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MARCH 1961

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A Journal for All Science and Mathematics Teachers

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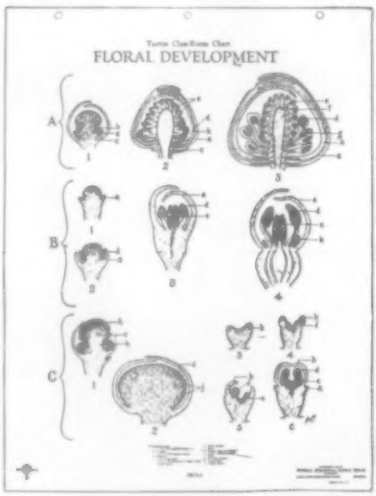

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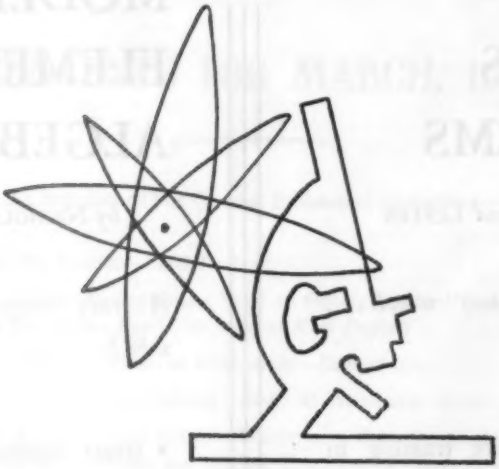

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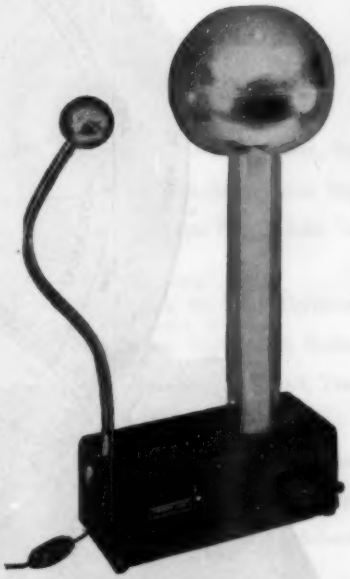

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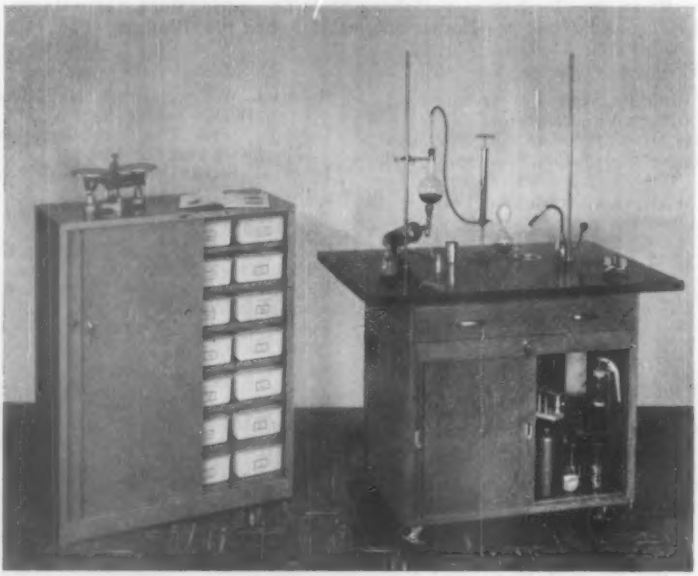

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How to Win An Argument
(The General Problem of Definition)

Kenneth E. Lake
Bradley University, Peoria, Illinois

We are, of course, not very much interested in arguments between persons who really do not want to find out if they are wrong. We are interested in arguments where the participants want to find out who has the strongest argument—even if it means giving up some cherished idea. We hope that the participants in our argument will try to beat their own best points, and aid their opponents in making the best possible statement of the opponents' case.

Arguments are carried on with guns, knives, fists, examples, experiments and words, among other things. I think we can agree that guns, knives and fists do not represent tools in the kind of argument in which we are interested, but rather they represent the failure of argument. "Might makes right" is usually discredited—at least verbally. But while we are being honest let us admit that appeals to force are very common. Such appeals are hardly less deadly to right when they take the form of economic or social sanctions. However, for the time being, we shall leave examples and consider words.

A common challenge in argument is "Define your terms." This challenge usually has the effect of completely bogging down the argument and resulting in a win by default for the challenger, though it leaves everyone with a bad taste. Why is this so? Why is it so hard to define one's terms? We shall investigate this problem by asking an odd question: Is it possible to define a word in terms of other words?

It is fairly obvious, when we think about it, that words do not carry their own definitions. A person has to be told that "Der Hund" means "the dog" and that "bellt" means "barks" before he will understand that "Der Hund bellt" means "the dog barks," (providing we know what this last means). We heard somewhere a story about Adam and Eve at the time they were naming the animals. Adam would bring each animal forward and Eve would name it. Adam brought up one animal and Eve named it "bear." He brought up another which she named "elephant." Eve did the naming with such speed and assurance that it began to get on Adam's nerves. He brought up the next animal and when it had been named "pig" he asked her why she had named this particular one "pig," why not the last one. "Well," Eve replied, "this animal looks more like a pig than anything we've seen so far."

Suppose you are in a discussion and you receive the challenge "Define your terms." You are serious so you start in bravely. But is your opponent satisfied with your definition? Of course not, he's out to win. He points out that you have used new words in your definition that he doesn't understand. Each of these new words must be defined or else you just haven't done your job. This seems to be a reasonable request, but watch out, do not use a critical word that you have used before. If you do your opponent will pounce on you with the charge "vicious circle!"

The author once looked up the word "reddle" in a small dictionary. "To reddle" meant "to raddle" and "to raddle" meant "to ruddle." Finally under the last entry we found that "to ruddle" was "to color with red ochre." The last was a help. If it had said "to reddle" we would have been lost. We would have had a vicious circle. Try this sometime with any dictionary: pick a word, any word, write down one or two words (exclusive of prepositions, articles or conjunctions) from the definition. Then look up those words and add one or two words from their definitions to your list. See how quickly you run into one of the words you have already listed—a vicious circle. You are *certain* to do so if your dictionary tries to define every word it uses! And what if it uses some words that it doesn't define?

We can make this situation a little clearer perhaps by stating and proving a theorem. *No word can be defined in terms of words alone.* We have agreed that no word should be used to define itself and that every word in the definition must be defined.

Proof: Consider any word w which is to be defined. (The symbol w is not the word we are considering but a variable which could be replaced by any word. For example, in place of w we might write "dog," "triangle," "democracy," or "beauty.") In defining w we shall have to use at least one new word w_1. We might write $w = d_1(w_1)$, where

$d_1(w_1)$ is a definition of w which uses the new word w_1. Now, according to our assumptions, we must define w_1. When we define w_1 we must use at least one new word w_2 which is different from w and w_1. We could symbolize this by writing $w_1 = d_2(w_2)$. In defining w_2 we must use at least one new word w_3 which is different from w, w_1 and w_2. Obviously we could continue this process for a "long time." We would as a result get a long list of statements looking something like this:

$$w = d_1(w_1)$$
$$w_1 = d_2(w_2)$$
$$w_2 = d_3(w_3)$$
$$w_3 = d_4(w_4)$$
$$\vdots$$
$$w_{n-1} = d_n(w_n)$$
$$\vdots$$

The first set of dots says "Keep up what you are doing until you get to the definition of w_{n-1}." However, the second set of dots say "Keep on doing what you have been doing *forever*." Notice how neatly the symbols express a fairly complicated idea: the idea of definitions going on and on, always in terms of words that have not been used before.

Now we are ready to get down to cases. The list either ends or it does not end. If it ends, it ends at a particular entry w_{n-1}. But this word is defined in terms of w_n which, since the list ends, will be left undefined. Therefore, according to our agreement that every word in a definition must be defined, we have no definition. We are stopped along this line of thought, so we shall take the other path. Suppose the list has no end! Our list of words would be infinite! We would have an infinite number of words, *all different*. But is this possible? If our language contained an infinite number of words we could not have an unabridged dictionary, but we do have an unabridged dictionary, therefore the number of words in our language is finite, limited, a definite number. We believe that with a little reflection you will agree that it is not possible at any conceivable point in history for mankind to possess a language containing an infinite number of words. Thus, we are stopped again and this time there are no more alternatives to be considered. We must conclude that, as we have described them, definitions in words alone are impossible. Our proof is complete.

This result seems quite interesting to us. Perhaps we will want to think about it for a while. Possibly this example will begin to show us that mathematics has something to say about things other than the merely quantitative.

If we are mean enough, or want to win an argument badly enough, we can use this theorem to our advantage. Rule Number One for winning an argument: ***insist upon definitions in terms of words.*** No matter who your opponent may be you have him caught if he agrees to your conditions. Now watch! Don't let him be circular. Don't let him use things other than words (or similar symbols) in his definitions. We do not recommend this method if you wish to retain your opponent as a friend or if your opponent is the type to abandon verbal argument for more primitive methods.

Let us review what we have done. We started with some agreements about definitions. Let's call these agreements *assumptions*. We considered in a logical manner the possibility of defining a word in terms of words alone. We considered the two possible alternatives and found that each was impossible. Consequently our conclusion was that *under the agreed upon assumptions* definitions in terms of words alone are impossible.

We should note well the crucial point: we were able to get the conclusions we did *because of and only because of the particular assumptions which we made previous to our proof*. What if we were not restricted to words alone? What if we were to allow circular definitions? Or, what if we did not insist that *every* word in a definition be defined? Look back at the proof of our theorem. Would it still be a proof? It appears that any one of these changes would force us, if we lacked further information, to conclude that definitions were possible. Each of these alternatives results in a different type of solution to the problem of definition, and we find each solution used.

A scientist would be quite unhappy if all of his definitions were in terms of words alone. Words are not his subject matter. He hopes that the words he uses are at least partially about the stuff out there that we look at, eat, and bump our shins against called *reality*. Thus the scientist will insist on *operational definitions* which he hopes are more than word games. If the scientist talks about a line he is not so interested in defining it in words as in knowing how he can know he has one and how it is to be measured.

Circular definitions are usually frowned upon, especially when used by someone else. It's probably a good idea to frown on them, but we ought to be fair and frown on our own circular definitions. For example, we might say that a line is the shortest distance between two points, then we might say that a point is the intersection of two lines. Since "bovine" means "cowlike," it is circular to say that a cow is a bovine animal. For a multitude of examples of this sort take any dictionary and follow up a word as was suggested above. As in the case of lines and points, if a word is abstract it may be difficult to know when one is being circular in dealing with it.

New Wine in Old Bottles*

Cecil B. Read

University of Wichita, Wichita, Kansas

Last spring I was honored by being asked to be one of the principal speakers at a conference of mathematics teachers held at Normal, Illinois. I received the usual complimentary remarks at the meeting, but of much more interest to me, I have had correspondence with more than a score of teachers who were present at that meeting. Since much of what I said then is applicable to the topic assigned to me here, and since it is probably true that no speaker ever gives a talk without wishing afterwards that he had the privilege of revising what he said, I have chosen to take this method of approach—adding, revising, and omitting. I used for my topic at that meeting—New Wine in Old Bottles, and I think it still not inappropriate.

Within the last few years, perhaps ten or a dozen, we have had many suggestions for overhauling our mathematics curriculum. Some of the suggestions have come from young men—some from those who are perhaps not young in years, but feel young in their viewpoint. Perhaps their attitude might well be expressed by a quotation from the prophet Isaiah:

> Isaiah 43: 18–19 Remember not the former things nor consider the things of old. Behold, I am doing a new thing, now it springs forth, do you not perceive it?

I think there is relatively little disagreement with the premise that the continual development of mathematics calls for new objectives, new curricula, new texts, new methods of teaching, and new methods of teacher training. This has sometimes been called "modernizing" mathematics. But when we call for new things, we need the Biblical warning.

> Luke 5: 36 No one tears a piece from a new garment and puts it upon an old garment. . . . If he does he will tear the new and the piece from the new will not match the old.

> Matthew 9: 17 Neither do men put new wine into old bottles; else the bottles break and the wine runneth out.

I would be the first to admit that there are several topics which are no doubt out of date. I would be also the first to claim that it is doubtful if you could get a dozen teachers to agree on what topics are outmoded and which are absolutely essential, but, using my title, "New Wine in Old Bottles," we must be very careful that we do not merely

* Presented to the Mathematics Section, Annual CASMT Convention, Detroit, Michigan, November 24–26, 1960, under the program title: "Challenges and Guides to the Individual Teacher Raised by the Various Study Group Projects."

introduce some new topics such as: numbers versus numerals, sets, mathematical logic, Boolean algebra, non-Euclidean geometry, topology. It will not do to merely put these new wines in our old bottle of a mathematical curriculum. The important thing, if we are to have a truly modern mathematics, is to revise the way in which we approach the material which we teach. To me it makes relatively little difference just what topics are included, although I agree there should be some uniformity and I would be willing to eliminate certain topics; but, again, it is the method of approach.

New does not merely mean a rearrangement of topics in the text; it does not mean a text printed in color, neither does it mean simply adding several enticing topics to an already overloaded curriculum. We must strive for a proper balance. On the one hand we must not throw out the old merely because it is old; neither must we try to teach advanced concepts to substandard students. A book may bear a 1960 copyright but still be in the spirit of 1860.

Before we completely tear up our curriculum let us recall that we must not fall into the trap of assuming that merely because something is one hundred, or two hundred, or three hundred years old, it is without value and useless. I am not particularly musically inclined but my friends who are assure me that the attempt to use a phonograph of the vintage of 1920 is completely out-of-date as compared with the modern Hi-Fi and stereophonic sound. I do not think I would in any way disagree with this statement. However, this does not imply that because the multiplication table is more than five hundred years old it should be discarded. Recently, I reviewed a paper submitted for publication in SCHOOL SCIENCE AND MATHEMATICS, containing the statement "It is no longer necessary to teach fundamental operations, since calculating machines are now available." We have developed new geometries since the time of Euclid; this does not mean that Euclidean geometry is incorrect or useless.

Sometimes the classroom teacher feels confused. "Just what is this modern mathematics?" is a question often asked. Probably no single person can give a definition with which any other individual would agree completely. Nevertheless, there are certain general concepts upon which there is rather universal agreement. One method by which an understanding can be obtained is to read material put out by various groups such as the School Mathematics Study Group, or the Illinois Group, or the Maryland experiment, or the Mathematics Commission of the College Entrance Examination Board. Another method is to consider reviews of recent textbooks in the field. Frequently the reviewer points out in what manner the textbook tends towards the modern approach and in what manner it is classified as traditional. Unfortunately, in many cases the term "traditional"

seems to be one of utter condemnation. We must realize that something is not wrong merely because it is old or traditional. Some traditional material still has great value. European countries, to say nothing of the Soviet Union, seem to be turning out competent mathematicians under what some would term an old fashioned, conservative, and outdated curriculum.

What should be included in a modern mathematics course? I can find many answers: the base of our number system; the distinction between numbers and numerals; sets; mathematical logic; probability; statistics; Boolean algebra; vector analysis; matrix theory; topology; non-Euclidean geometry; calculus; you can extend the list. But merely because you are teaching something about number systems based on 2 or 5 or 12; or about sets; or about the geometry of Lobachevsky does not mean that you are teaching a modern course. I repeat—let's not put new wine in old bottles. It is not making mathematics modern to merely include calculus, or sets, or matrix theory, or the history of mathematics, or any other topic. Johnny in the elementary grades may not think of new wine in old bottles when he complains that today the teacher says 3 and 1 are 4 while yesterday it was 2 and 2. Yet, if the teaching is purely mechanical, he has a point, and a logical one.

You can also find differences of opinion. The Commission on Mathematics of the College Entrance Examination Board at first suggested calculus; now they are less certain of its proper place in the secondary school. There have been unfortunate experiences where a young teacher just out of graduate school tried to introduce mathematical logic to his high school sophomores, at the same level of rigor as a third year graduate class.

What is needed is a new appreciation; a new approach. Just because someone has called a topic "modern" does not imply it must be good. One danger in pushing subjects like algebra into the 5th or 6th grade or calculus into the secondary school is the possibility that the pressure of time may result in superficial coverage. The student meeting the concept again in high school or college may feel this is "old stuff" and hence fail to grasp that a more rigorous approach is now being used. He sometimes fails the later course.

We wish to teach more mathematics more creatively, to teach the true nature of mathematical thought; we must supply motivation and purpose; in other words, creative teaching—not merely addition of topics to an already overburdened curriculum; and not merely surgical removal of certain topics which some so called authority designates as obsolete (while his colleague, of equal authority, denotes them as essential).

Much that is old is of great value; it may be we need to attack it

from a new point of view. I am one who agrees wholeheartedly that we need to emphasize interrelationships among various topics in mathematics. Some call it unification, some fusion, some integration. But cutting up an arithmetic, a geometry, an algebra, and a trigonometry text book and reassembling them in some other order does not make a unified course. Again, I agree that the concept of sets provides a fine opportunity for integration. I radically disagree that that forms the only such opportunity.

The fundamental operations have changed in definition over the history of mathematics. At one time the operations included notation and numeration as well as duplation and mediation. It would almost seem that at this period in history some people have the idea that the use of sets is one of the fundamental operations of mathematics.

I have been impressed with the fact that some quarter of a century or more ago everybody thought that the unifying concept in elementary mathematics was that of function. Yet, I recall that in my graduate work Dean Eisenhart, of Princeton University, spent more than three weeks going over the difficulties which mathematicians have had in trying to formalize and understand the concept of a function. Now I am suddenly amzaed to discover that this, by the modern use of sets, can be made crystal clear to the high school freshman. Frankly, I doubt it. Possibly all of the great mathematicians who had difficulty in understanding some of these concepts were realy not great.

Older texts defined a function as either single valued or multiple valued. A newer definition introduces the concept of ***relation*** for what was previously spoken of as a multiple valued function. Even though the newer definition may be preferred by the teacher, and I would agree, many students are going to encounter classic references which use the term function to mean either a single valued or a multiple valued function. It is hardly fair to the student to withhold this information from him.

One major change in viewpoint which I believe has great merit is the changing attitude towards rigor. I believe sincerely that we must use a rigorous approach but with the qualification that it must be not beyond the capacity of the student to appreciate such rigor. It is now fairly generally recognized that it might be better to approach Euclidean geometry with a different set of postulates, for example the postulate of betweenness; and to postulate congruencies in the case of triangles, rather than give a proof which is really not logically rigorous. But, I have encountered many experienced high school teachers who fail to see where there is anything lacking in the traditional Euclidean postulates. Certainly many of you have encountered high school students who see no reason for postulating that which seems

obvious. By all means, let us emphasize rigor, but let us not attempt to emphasize rigor beyond the level which can be understood by the student. There is a pedagogical problem here perhaps as important as a mathematical problem. Too often the student introduced to geometry or to some of the concepts of the number system feels that we are trying to prove what any fool knew already was true. So, in introducing such topics I plead for great care in making sure that the student realizes that there *is* an inherent difficulty. To state it another way, it is rather foolish to show the student how to remove a logical difficulty when he sees no difficulty whatsoever. Geometry as it can be taught in the high school is frequently not pure logic but instead only plausible reasoning.

We must as teachers continually be aware of the fact that genuine understanding of mathematics requires training; it is not something that the student inherits. The student must learn to read and understand. Sometimes we make the mistake of assuming that the student in plane geometry is well grounded in deductive logic, and may make an equally serious mistake by creating the impression that arithmetic or algebra has no connection with logical organization.

I am always hopeful but rarely do my hopes meet with what I might call success. Each year, in introducing some material in the field of the theory of equations—whether in the latter stages of an advanced algebra course or in a formal course of theory of equations—I am always hopeful, I say, that I will not find students greatly surprised to discover that there could be a theorem in algebra. But, invariably, I am met with the statement, "But I thought theorems belonged only in geometry." Perhaps in the last few years the situation has improved somewhat, but still there are those students who believe that theorems belong only in the field of geometry.

Since we have mentioned geometry more than once, let us consider it in a little more detail. Over a period of years I have claimed that the subject matter of Plane Geometry is not particularly suited for a year's work at the secondary school level. Certainly Euclid was not writing for students of high school maturity. I have felt for a quarter of a century that we could simplify much material by introducing some elementary coordinate geometry. Not only would this be a unifying concept between algebra and geometry but it would in many cases greatly simplify the student's understanding of the nature of an algebraic approach to a geometric problem. In my opinion, in no way would the student be lacking in his mathematical education. For years I have made this statement and I have seemed to be a voice howling in the wilderness. Now we are beginning to move in this direction. For more than 25 years there has been a body of material which suggests that we might well combine plane and solid geometry

in one course. In the early thirties I served on the College Entrance Examination Board, grading in the field of geometry. We had at that time a couple of examinations in unified courses; for example, the 1930 examination had Mathematics *CD*, plane and solid geometry, major requirement ($1\frac{1}{2}$ units). There was likewise Mathematics cd, plane and solid geometry, minor requirement (1 unit). These series were given at least through the period 1921–30. Nevertheless, they never seemed to become very popular. Perhaps we are returning to this situation, not from a lack of popularity but because of a new idea as to what is modern.

A couple of summers ago a graduate student working under my supervision attempted to find out what should be the content of a one year course in plane and solid geometry. I thought I would be able to guide him in his reading. We found numerous references which suggested that much could be eliminated and often this was called "deadwood." However, an article that actually specifies either what could be eliminated from our present courses or what should be included in a combined course was extremely rare. It is only recently that such an article appeared in the November, 1959, number of *The Mathematics Teacher*. Perhaps we are too prone to state what should be done rather than specifying some of the details of how the condensation might be made.

There is probably no better subject than mathematics to help the student learn verbal precision. But it must be realized that the ability to clearly express certain concepts tends to develop gradually. There has, in the last few years, been a great tendency to express all definitions in the form of singling out certain sets or types of sets. This has been, in most cases, eminently satisfactory. However, I think one needs to realize that the important concept we are talking about here is that of preciseness and there is no reason why definitions must be phrased in terms of sets. If we are careful to avoid ambiguities and if we are likewise careful to point out alternative definitions when they do exist, we will have accomplished a great deal in improving the efficiency of definition and hence improving the ability to communicate accurately.

If we turn to the subjects of arithmetic and of algebra we find criticism of much that has been taught as useless formal manipulation. It would be hard to find complete agreement as to what is useless manipulation. However, we must be careful that we do not present arithmetic or algebra or any other phase of mathematics as an assortment of devices often unfortunately called by the teacher an assortment of tricks, without any real appreciation of what mathematics is concerned with.

We hear far too often that mathematics is a series of techniques.

Some would delete this completely. I feel some of the drill is essential, but it must not replace an understanding of the reasons underlying the procedure. With proper understanding, I believe the amount of time required in routine drill will be radically diminished. At one level, this may apply to factoring, at another level, to the multiplication table, at another to the methods of integration. I find students of engineering mathematics reluctant to spend time on integration. Why waste time, they ask, when integral tables are available. Yet occasionally, I find a self-taught so-called engineer calling for help because an integral is not listed in any available table. Yet, a very simple understanding of the reasons underlying some work in trigonometric identities would have eliminated the difficulty in short order.

No doubt you have encountered the situation where you have tried to interest the students in fractional and negative exponents, or it may be that you have found students are not particularly thrilled with identities. Now it is all very well to make use of a fact which you are well aware of—that when a student reaches a certain stage in the calculus facility in handling fractional and negative exponents, or facility with transformation of trigonometric expressions into other forms is almost imperative if he is to succeed in integrating certain expressions. But, if this is the sole reason for introducing such a subject, some students will take the point of view that with such a boring introduction they are not at all interested in going on to further work. It is not wasted time to arouse interest. If we can solve interesting problems while we are introducing some technique we may actually save time. Moreover, if the student can find some understanding of the purposes and methods of mathematics and how the technique he is now studying can be used, then he is much more likely to really learn what he is taught than to merely go through a routine technique. Far too often the teacher is guilty of making a statement such as "Now the trick in solving this problem is . . ." No wonder the student thinks mathematics is a collection of tricks. I feel that it is not adequate to tell the student "You do not understand now why you need this material, but wait until you get into a later course and you will then wish you had studied the material."

If you agree with me this means that we must impress the student with the fact that each topic we introduce has some connection with a genuine problem. Many of you have no doubt seen examination questions which say "solve this problem by a specified method." I should like to introduce the idea that these are not good examination questions. Fundamentally we are interested in the student's ability to carry out the solution of a problem. I should like to give two quotations from Chrystal's famous two volume algebra, first published in 1886: "The main problem which arises in connection with every

system of equations of condition is to find a set or sets of values of the variables which shall render every equation of the system an identity, literal or numerical." But stop a moment! I thought the concept of sets was something modern! Here we find it in a book written seventy years ago. Let us continue: Chrystal further states, "No matter how elaborate or ingenious the process by which the solution has been obtained, if it does not satisfy the equation it is no solution; and on the other hand, no matter how simply obtained, provided it does stand this test, it is a solution. In fact, as good a way of solving equations as any other is to guess a solution and test its accuracy by substitution." This may seem horrifying to the teacher who in algebra, for example, has insisted on a test—solve the quadratic equation below by the method of completing the square, or perhaps—solve the equation by use of the quadratic formula. I hold that if the problem cannot be so phrased as to require the use of a particular method then it is indeed doubtful that the problem has any business being on the test. It does not take a great deal of ingenuity to so phrase a problem that the student must utilize a specific method. I will grant that Chrystal's solution by guessing may be of little use in solving another similar problem; but, if the student is clever enough and has enough understanding of mathematics to use this method, then let us criticize the teacher for the phrasing of the problem and not mark down the student for his understanding of mathematics. I might point out in this connection that one of my objections to certain forms of multiple choice tests in mathematics is that it is often easier to test all the answers given than it is to solve the problem. This may require some careful phrasing of test questions and, in my opinion, it is occasionally a good idea to include the choice "none of the preceding answers" and have this choice the correct answer. The student working with a multiple choice test and not getting one of the answers often is intelligent enough to know that he has made a mistake.

A point of view has been expressed, and it indeed has considerable merit, that conventional textbooks are in error in placing so much stress on detailed step by step rules for manipulation and simplification. Those holding this point of view contend that such rules should be invented by students since they are merly shortcuts in applying basic principles. The other side of the picture is perhaps well presented by M. H. A. Newman in his presidential address to the British Mathematical Association in 1959 in which he pointed out that it may be that if the students think hard enough and long enough and are clever enough they can discover all the rules; but, since the deriving of shortcuts from basic principles covers some of the finest achievements of the greatest mathematicians, Professor Newman does not feel that

the interval is a period of suspense during which the work remains meaningless. He points out that someone who knows very simple facts of electric currents and their behavior in wires knows something about electricity even though he may not know how to deduce these laws of behavior from Maxwell's general equations of electro-magnetism. Professor Newman then points out that a student may learn something about using logarithms and have a coherent body of facts about them and will have learned some mathematics even before he finds out (which Professor Newman says he will do with even more pleasure) that it all depends on the laws of exponents.

I am not sure that I wish to go all the way with Professor Newman's point of view; namely, that the systematic development of the deductions from a set of abstract laws and the study of the uses that can be made of them is possibly the most important branch of mathematics, even so humble a set as the laws governing the use of logarithms given as rules without reasons. On the other hand, I am not sure that I want to go along with the point of view that no one is really ready to hear about numbers until they are thoroughly familiar with the entire concept of topological groups. In other words, it is somewhat a matter of degree as to how far you are prepared to push your principles. All of you, as well as your students, have been perhaps perturbed by the fact that so many books state that "it can be proved," or "the proof of this is left for a later stage of development," or, "in a more advanced course, it will be proved." After a while the student begins to wonder if he ever reaches the stage where this statement will not be made. The pursuit of a final explanation will never perhaps succeed. It is perhaps better to recognize that each layer has its own intrinsic value, greater or less. I know of no better way to put it than was expressed by Professor Newman in the presidential address I referred to—that, "as we ascend the skyscraper of modern mathematics, in which there are no elevators, the pleasure and enlightenment to be obtained is all the greater if we are thoroughly at home on one floor before starting to climb to the next."

It is the rare textbook, either in mathematics or in the teaching of mathematics, that spends a great deal of effort on the historical development of the subject. I have tried for years to point out to my mathematics classes that the difficulties encountered by the individual in his understanding of mathematics often parallel those which were encountered by the race as the subject developed. If the student finds the concept of long division difficult to master, he may gain some comfort from the fact that this subject also took the race several hundred years to thoroughly assimilate.

You may ask what I would do, and what I would not do. Your own

examples are as good as mine. Let me suggest as examples of the old which should be discarded: Pi equals twenty-two sevenths or 3.1416; the cost of a parcel post package drawn as a straight line graph. As examples of what might be done: Why things are done in mathematics, not merely how; how mathematics holds together in an interrelated logical structure; or the possibility of a trignometry textbook without solution of triangles by means of logarithms.

Finally, as an example of how *not* to introduce sets into a course:

A trigonometry teacher defines the universal set as consisting of four elements, namely the four quadrants of the plane. The set s is defined as those quadrants in which the sine is positive; that is, the set s is {I,II}. The teacher now says, "We will define the complementary set as $\bar{s}$, which is those quadrants in which the sine is not positive. Now, in like manner, if we define the universal set as consisting of four elements (the quadrants I, II, III, IV), the set t will be those quadrants in which the tangent is positive; namely, {I, III}. The set $\bar{t}$ will then be those quadrants in which the tangent is not positive. The teacher now proceeds to say—"If we now wish to know in what quadrant an angle terminates if a sine is positive and its tangent is negative in terms of set notation, we seek the union (or is it the intersection?—I'm never quite sure which is which—well, I don't know that it matters) of these two sets. The union of these sets s and t is the set {I}, hence the angle terminates in the first quadrant."

At this point one of the students says—"What if the sine of the angle is neither positive nor negative, but zero?" The teacher replies, "This is the null or zero set; that is, there are no values here." This seems to confuse the students a little and another student asks, "What about the case where the tangent is infinite?" The teacher replies, "Well, this is another case where the tangent does not exist so this is the null set. In other words, if the angle terminates on a dividing line between quadrants, this forms the null set."

You may not believe it but this presentation was not done by a student or cadet teacher but by a high school teacher acting as a supervising or critic teacher handling students enrolled in a teacher training institution—not in the state of Kansas, I may remark. I had been invited to listen to this presentation by a high school principal, who proudly pointed out that here was a teacher who was introducing the concept of sets into trigonometry and hence had a modern approach. Possibly I am prejudiced, but I have the feeling that this teacher confused the students much more than would have been the case with a traditional treatment—at any rate it is hard to imagine how they could have been worse confused. The mere introduction of the word set or sets does not make modern mathematics.

The College Entrance Examination Board's commission on mathematics states that a sound teacher-education program can be developed around a major of 24 semester hours beyond the calculus. Certainly this seems adequate for a sound preparation providing this is done in the modern spirit. I hope it will not be misunderstood that I am against such a major. However, coming from what the Colorado teacher calls the east, and you in Michigan call the west, and we in Kansas call the Middle West, I find that in my state and surrounding states it is not at all unusual to have a major consist of 10 to 12 hours of mathematics beyond the calculus. I would like to sound a note of warning. We must be careful that we do not make the requirements for the major so very severe, as contrasted with other teaching fields, that students become discouraged before they even enter upon a career or preparation for a career of teaching mathematics. In other words, we must be careful that we do not set our sights so high that no one will wish to become a mathematics teacher or the number will be so few that we will have an even greater shortage of mathematics teachers. I believe it would be better to have some teachers who have some of the ideas of modern mathematics but may not perhaps meet this ideal qualification than to have students completely discouraged by the long pull ahead of them before they can enter a teaching career, especially when this may not be the case in other fields which offer equally lucrative employment.

Last fall I was privileged to hear Dr. John R. Mayer speak to a group of mathematics teachers in Kansas. Dr. Mayer made a point which some of you may have heard him make elsewhere but it was so impressive to me that I think it bears repetition. He pointed out that an educated person prides himself on a knowledge of music, literature, art, and similar topics. If he does not have competence in these subjects he attempts to conceal this fact and is, in fact, rather ashamed. On the other hand, it seems to be a matter of social pride to brag about one's lack of competence in mathematics; for example, the inability to balance a check book, or the inability to make out an income tax form, or even the inability to keep a bridge score. Think this over for awhile and ask yourself whether we can expect to proceed to greater heights in the field of mathematics if this is the socially acceptable thing. I have no solution but it bears considerable thought.

Just a word of warning: If you are attempting to keep up in the field, you will find many groups making intensive study, and offering suggestion for change—which, to me, seems sometimes to be considered as synonymous with improvement. But with various groups, such as the Illinois Study Group, the Maryland experiment, the School Mathematics Study Group, the Commission of the College Entrance Examination Board, one can not help but note that al-

though there is rather close agreement on general philosophy, there are differences of opinion as to details. This is normal, it is to be expected with any new proposal. Do not let it disturb you; probably even the proponents of any plan would not claim perfection. I would stress the challenge: to improve understanding of mathematics. As for a guide: Select what seems feasible for your class, or for your school. Do not be afraid to experiment; but do not make changes merely to be different, and do not discard the old merely because it is old.

Perhaps the true spirit of what we are trying to accomplish is expressed if we try to answer questions such as were raised by the poet Alexander Pope: "Ah, Why, Ye Gods, should two and two make four?" Let us enjoy new wine, but be careful to put it in new bottles.

DRUG FROM MUSHROOMS ACTIVE AGAINST CANCER

A new antitumor agent, calvacin, has been found active against 14 various types of cancer and is now being prepared for clinical trial, probably withing six months.

Calvacin, extracted from the fruiting bodies, or sporophores, of the giant puffball mushroom, *Calvatia gigantea*, is a "nondiffusible, basic mucoprotein." This type of drug is not now available for treating malignant tumors.

The first clue to the tumor-stopping ability of calvacin was discovered several years ago by a Michigan State University team.

Since that time, MSU workers have screened hundreds of C. gigantea strains to find those that produce the most calvacin in the shortest time.

Scientists at Armour and Company, Chicago, isolated the calvacin from the sporophores and developed the fermentation process.

A third group at Sloan-Kettering Institute for Cancer Research, New York, tested the drug against 24 types of mouse, rat and hamster tumors. In 10 types of tumors, the drug prevented growth beyond a size one-fourth to three-fourths that of the controls. In four types of tumors, calvacin stopped the growth at one-fourth the size of the controls, In one type of cancer, the drug was toxic to the animal.

Calvacin was scheduled to be on clinical trial by now, but difficulties in the fermentation process indicate that the drug will have to be extracted from the fruiting bodies instead. If all goes well, calvacin will go on clinical trial in New York by mid-1961.

The research was reported here in Science (Dec. 23), official journal of the American Association for the Advancement of Science, by Drs. J. F. Roland, Z. F. Chmielewicz, B. A. Weiner, A. M. Gross, O. P. Boening, J. V. Luck, all of Armour and Company, and Dr. T. J. Bardos, formerly with Armour, now at the University of Buffalo, N. Y., also Drs. H. Christine Reilly, K. Sugiura and Dr. Stock of Sloan-Kettering; and Dr. Lucas, R. U. Byerrum and J. A. Stevens, all of MSU in East Lansing, Mich.

Comparison of Two Rating Scales Used to Obtain Student Reactions to Chemistry Teachers

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High school science teachers are required to take many courses in professional education before being licensed to teach. The purpose of most of these courses is to prepare teachers to work effectively with adolescents. After entering the classroom, a science teacher should try to get reliable information on the effects he is having on students. One of the best sources of this information is the students. They know whether they are interested or bored, are working or loafing, are confused or working with clear purpose, and are enjoying or hating the course. They know these and many other things and they can give reliable reports on their opinions and feelings by means of a well-constructed questionnaire.

Students, like school administrators, when answering a scaled questionnaire, tend to judge most teachers as "good" or "excellent." This fact raises the question—What advantages, if any, would result if a five-point scale (The Very Best, Very Good, Good, Average, Below Average) were substituted for a four-point scale (Excellent, Good, Average, Below Average)? This question was made the subject of an investigation in which one hundred chemistry teachers participated.

Procedures Used

The questionnaire and the procedures used to obtain and summarize student reactions are here briefly described.

a. Two forms of the same questionnaire were used. One form differs from the other in only one respect, namely, each of the questions is accompanied by a five-point rather than a four-point scale.

The first of ten questions, making use of the four-point scale, is as follows: What is your opinion concerning the knowledge this teacher has of the subject taught? (Has a thorough knowledge and understanding of his field?) Excellent, Good, Average, Below Average.

The ten scaled questions in the questionnaire follow. What is your opinion concerning:

1. The knowledge this teacher has of the subject?
2. The ability of this teacher to explain clearly?
3. This teacher's fairness in dealing with students?
4. The ability of this teacher to maintain good discipline?
5. The sympathetic understanding shown by this teacher?
6. The amount you are learning in this class?
7. The ability of this teacher to get things done in an efficient and business-like manner?

8. The ability this teacher has to make classes lively and interesting?
9. The value this subject has for you?
10. The general (all-round) teaching ability of this teacher?

Each question is accompanied by a sub-question in parentheses which helps to clarify, as illustrated above. The same four-point scale accompanies each question.

Also, the questionnaire contains two un-scaled questions which call on students to name one or two things they especially like about the class or teacher, and one or two things they dislike. No further reference will be made to these questions because they have no bearing on this investigation.

The second form of this questionnaire differs from that described in only one respect. Each of the ten scaled questions is accompanied by a five-point (The Very Best, Very Good, Good, Average, Below Average) rather than the four-point scale.

b. Of 240 high school chemistry teachers who were invited to participate in this study, 100 accepted the invitation. These 100 "volunteers" represent a degree of selection. It is reasonable to think that a greater percentage of the more confident teachers than the insecure make up the group under discussion. The assumption is supported by the fact that the median averages of student reactions to these 100 volunteers are higher than this investigator obtained by means of the same questionnaire when all teachers in unselected schools have used the instrument.

c. On an announced date, half of the 100 participating teachers obtained the reactions of their students from one chemistry class by means of the four-point scale. The other half used the five-point scale to obtain student reactions from one class. Ten days later the scales were switched and the procedure was repeated. Thus each teacher was rated twice by the same class. The enrollment of these classes ranged from 14 to 32 students with a median of 26.

d. These 100 chemistry teachers were instructed as follows: "During the fifteen minutes required by students to answer the questionnaire, exchange classes with one of your colleagues. In accord with this procedure, someone other than yourself should be in charge of your class while the questionnaire is being answered. As soon as the students have answered the questions, the person in charge of the class should collect and seal the questionnaires in a self-addressed envelope provided for that purpose. The envelope should then be placed in the mail."

e. The average of student responses on each of the ten scaled questions was obtained for each class. For example, the "point" average for a hypothetical class is obtained as follows:

Four-point scale	*Number of Students*		*Weight*		*Product*
Excellent	10	×	1	=	10
Good	3	×	2	=	6
Average	5	×	3	=	15
Below Average	2	×	4	=	8
	20				39

39 ÷ 20 = a point average of 2.0. As shown in Table I, when a "Point average" of 2.0 is arbitrarily converted into an average on the scale of 100, it becomes 90.

The same procedure was used to obtain reaction averages by means of the five-point scale, as here illustrated.

Five-point scale	*Number of Students*		*Weight*		*Product*
The Very Best	2	×	1	=	2
Very Good	9	×	2	=	18
Good	6	×	3	=	18
Average	3	×	4	=	12
Below Average	0				
	20				50

50 ÷ 20 = a point average of 2.5. As shown in Table I, this point average becomes 85 when translated into an average on the scale of 100.

Analysis of Data

Table I shows the distribution of the average of the reactions (obtained by means of two scales) to these 100 chemistry teachers. The averages falling at percentiles 10, 50, and 90, obtained by use of the four-point scale, are indicated by solid lines. The corresponding averages obtained by means of a five-point scale are indicated by the broken lines.

It should be noted that the averages obtained by means of the five-point scale (broken lines) are lower than the averages obtained from the four-point scale (solid lines). For example, on question ten the median average (50th percentile) is 91 when the four-point scale is used. The corresponding average for the five-point scale is 85.

The reactions averages obtained by means of the two scales are equally reliable. This conclusion is substantiated by the reliability coefficients obtained by means of the customary chance-half method. Excluding questions six and nine, the average Reliability Index for the questions in the four-point scale is .93. The corresponding figure for the five-point scale is exactly the same—.93. In both scales the Reliability Index for each question except six and nine is 90 or above.

TABLE I

AVERAGE RATINGS OF 100 CHEMISTRY TEACHERS OBTAINED BY MEANS OF A FOUR-POINT SCALE COMPARED (PERCENTILES 10, 50, AND 90) TO THOSE OBTAINED BY MEANS OF A FIVE-POINT SCALE

Scale steps	Point Av.	Scale Av.	Questions 1	2	3	4	5	6	7	8	9	10
Excellent	1.0	100										
or	1.1	9 9										
The Very Best	1.2	9 8										
	1.3	9 7										
	1.4	9 6										
	1.5	9 5										90
	1.6	9 4										
	1.7	9 3										90
	1.8	9 2										
	1.9	9 1										50
Good	2.0	9 0										
or	2.1	8 9										
Very Good	2.2	8 8										
	2.3	8 7										
	2.4	8 6										
	2.5	8 5										50
	2.6	8 4										10
	2.7	8 3										
	2.8	8 2										
	2.9	8 1										
Average	3.0	8 0										
or	3.1	7 9										
Good	3.2	7 8										
	3.3	7 7										10
	3.4	7 6										
	3.5	7 5										
	3.6	7 4										
	3.7	7 3										
	3.8	7 2										
	3.9	7 1										
Below Average	4.0	7 0										
or	4.1	6 9										
Average	4.2	6 8										
	4.3	6 7										
	4.4	6 6										
	4.5	6 5										
	4.6	6 4										
	4.7	6 3										
	4.8	6 2										
Below Average	4.9	6 1										
	5.0	6 0										

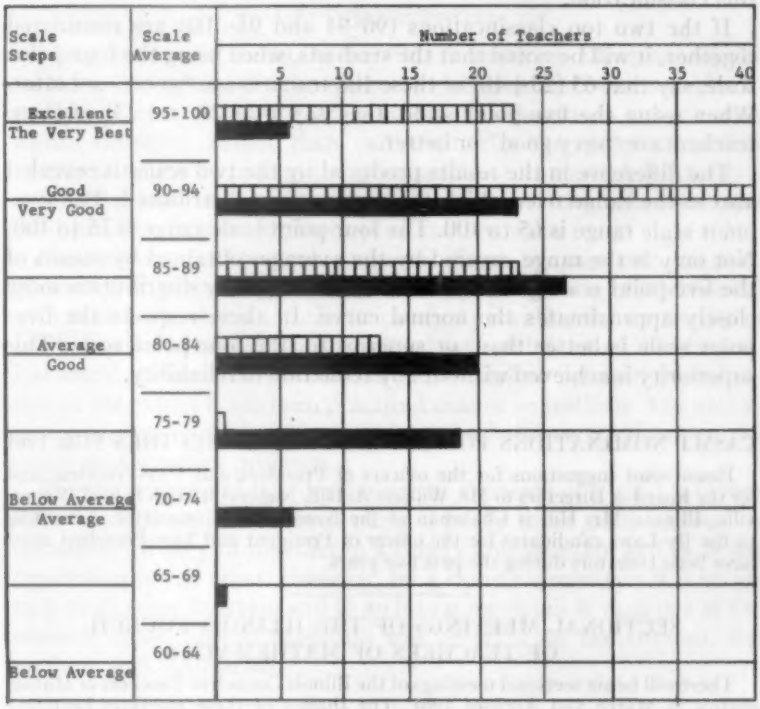
This table should be interpreted as follows: On question one (knowledge of subject) the average that falls at the 90th percentile when the four-point scale (solid graph line) was used to obtain student reactions to 100 teachers is 99. The corresponding average obtained by means of the five-point scale (broken graph line) is 95.

The "scale steps" are the choices available to students when answering each question. When using the four-point scale, the students could choose one of these four steps: Excellent, Good, Average, Below Average. When using the five-point scale, they could choose one of these five steps: The Very Best, Very Good, Good, Average, Below Average.

The "Point Averages" and the "Scale Averages" are defined on preceding pages.

TABLE II

COMPARISON OF STUDENT REACTION AVERAGES OBTAINED BY MEANS OF A FOUR-POINT SCALE AND A FIVE-POINT SCALE BY 100 CHEMISTRY TEACHERS ON QUESTION TEN (GENERAL TEACHING ABILITY)



This table should be interpreted as follows: The barred, horizontal column at the top of the table means that 23 out of 100 teachers received on question ten, by means of the four-point scale, averages between 95 and 100. When the students in one class of each of these same 100 chemistry teachers answered question ten using the five-point scale, only six teachers (solid, horizontal column) obtained an average between 95 and 100.

Comparison of the relative merits of the two scales is facilitated by concentration on only one of the ten questions, as illustrated in Table II. Here is presented the distribution of the student-reaction averages on question ten (general teaching ability).

The data in Table II show that the top steps in the five-point scale are used less frequently than are the top steps in the four-point scale.

When students used the five-point scale, only six teachers out of the 100 received an average in the top classification (95–100). In contrast, when the four-point scale was used, 23 teachers received an average in this classification.

If the two top classifications (90–94 and 95–100) are considered together, it will be noted that the students, when using the four-point scale, say that 63 (23+40) of these 100 teachers are "good" or better. When using the five-point scale, they say that 29 (6+23) of these teachers are "very good" or better.

The difference in the results produced by the two scales is revealed also in the range over which the averages are distributed. The five-point scale range is 65 to 100. The four-point scale range is 75 to 100. Not only is the range covered by the averages obtained by means of the five-point scale greater, but also the frequency distribution more closely approximates the normal curve. In these respects the five-point scale is better than, or superior to, the four-point scale. This superiority is achieved without any reduction in reliability.

CASMT NOMINATIONS FOR OFFICERS AND DIRECTORS FOR 1961

Please send suggestions for the officers of President and Vice-President and for the Board of Directors to Mr. William A. Hill, Naperville High School, Naperville, Illinois. Mr. Hill is Chairman of the Nominating Committee. According to the By-Laws candidates for the officer of President and Vice-President must have been Directors during the past five years.

SECTIONAL MEETINGS OF THE ILLINOIS COUNCIL OF TEACHERS OF MATHEMATICS

There will be six sectional meetings of the Illinois Council of Teachers of Mathematics in March and April of 1961. The themes of these meetings include—*The Function of Modern Mathematics*, *Meeting Today's Challenges in Mathematics*, and *Recent Developments in the Teaching of Mathematics*. These meetings are specifically designed for teachers at the elementary, secondary, and college levels. The dates, places, and chairmen of the meetings are:

Date	*Place*	*Chairman*
March 25	Monticello College, Godfrey, Illinois	Evelyn Trennt
April 1	Southern Illinois University, Carbondale	W. C. McDaniel
April 14	Eastern Illinois University, Charleston	Alphonso DePietro
April 15	Western Illinois University, Macomb	Jerry Shyrock
April 22	Illinois State Normal University, Normal	Hal Gilmore
April 29	Sterling Township High School, Sterling	Charles E. Schulz Chester Sherman

For detailed information please write to the chairman of the specific meeting as indicated above. For general information, write to:

T. E. Rine, Chairman
Public Relations
Illinois Council of Teachers of Mathematics
Illinois State Normal University
Normal, Illinois

Elements of a Good Program in Arithmetic*

Edward Sage
Livonia Public Schools, Livonia, Michigan

I. Introduction

Many years ago Gauss stated, "Mathematics is the queen of the sciences, and arithmetic the queen of mathematics." One would certainly not want to dispute this position of arithmetic in our scientific world. However, rather than call arithmetic the queen of mathematics it might be put into a more practical framework for today's world. Arithmetic supports and holds together the other areas of mathematics. It is the keystone of all mathematics.

Elementary arithmetical understandings tie together algebra, geometry, trigonometry, and calculus, as each in turn is interrelated with arithmetic. Arithmetic is the catalyst providing the continuity of mathematical ideas as more specialized content is learned. Mathematical learnings must be continuous, and therefore compartmentalization to the extent it has been practiced cannot be justified. The nature of a program in arithmetic must be considered as it relates to the entire mathematics program.

For the purpose of this discussion the elements of a good program have been divided into three parts. Ideally these parts cannot be separated for they fit together in a closely knit program and each one depends upon the other. However, for a closer examination it is necessary to do some isolation and to go into some detail in each one of the isolated areas. Special attention will be given to the content, the method, and the teacher.

II. Elements of a good Program

A. *Content*

Any arithmetic program must basically concern itself with counting and the nature of number. Counting is the foundation of all operation in arithmetic and attention must be directed to the quality and quantity of experiences provided in this area. A good understanding of counting is the background of all measurement and all operations. Most children approach counting through a rote pattern. As they grow in number concept the number words that they have learned are to take on certain meaning and have certain significance for them. Boys and girls must be given every opportunity to see the relationship of numbers to one another and in some way graphically portray this development. Most teachers use number charts, number ladders,

* A paper presented at the Annual Convention of the Central Association of Science and Mathematics Teachers, Detroit, Michigan, November 24–26, 1960.

or number lines of some form when working with children. Children also count pencils, books, other boys and girls, milk money, etc.

But many other experiences in counting have been pretty largely left to chance or have been neglected. What of the broad range of experiences that can be provided with various kinds of number lines? A child's first counting experiences deal with the natural numbers, 1–10, then to 20, and then later on to 100 and 1,000. Certainly a number line drawn to meet these specific needs is a very helpful instrument. In some cases it may be only a segment of a number line which shows desired relationships. Then this segment of the number line must be exploited to its fullest potential. Some ways this might be done is not only to let children count by ones, but by twos, starting at both even and odd numbers. Encourage them to see what really is happening. What is happening when one counts by fives? And certainly it is possible to count backwards as well as forward. The number line which shows the position of numbers graphically is a wonderful instrument for providing the concrete help in this kind of an operation. Later as children grow in their understanding of number on a number line, they will not only count forward and backward in terms of whole numbers. They will also see and learn that they can count forward and backward by a particular quantity that may be desired.

Along with and through this procedure we are helping boys and girls to discover that number is not only discreet as it is used in some ways but it is continuous as used most times. They will see that as they are counting objects that they are using number in a discreet role, but that every time some measurement is involved number as a continuous factor is being used. The number line itself can be used to show both the discreet and the continuous nature of number. And, when counting forward and backward along a line, it becomes evident that soon the line must be extended to the negative side of the "0" point. When one looks at the problem this way it is definitely seen that counting is not something that is done only in the lower elementary grades. The development and understanding of the manifold aspects of counting continue as long as one continues to concern himself with the use and study of mathematics.

Another important aspect of the content of the arithmetic program is the relationship of symbolization to the mathematical ideas involved. Number ideas, number concepts, number theory, are all quite abstract; they exist only in the minds of men who have these ideas. However, because of the need of having some common plane upon which to work and communicate men have agreed upon certain symbols to represent their mathematical ideas. The numeral itself is not number. It is only a way of representing number ideas and should be

considered as such and understood as such even at the elementary school level. Children should also learn that certain other symbols are a shorthand way of showing number operations and relationships.

Growing directly out of the understanding and practice of counting is the concept of group. Units are put together to form groups. Groups are put together to form other groups. Groups are taken apart to form other groups, etc. This is the logical way for man to organize his thoughts in terms of handling larger and larger quantities. Once a child has stopped thinking in terms of only individual units and has developed a group concept he is ready to start working on some of the more sophisticated operation of arithmetic. He is ready to begin adding, subtracting, multiplying, and dividing. But in these operations we are only grouping quantities together, grouping quantities apart, or comparing the size of various quantities or groups. Children should understand this idea quite well so that they need not guess which operation they are going to perform with the quantities found in some problems. They might simply ask themselves, "Is this a situation where numbers are being grouped together, and how might I most efficiently group these numbers together?" Or they might ask, "Is this a situation where I am asked to take a number apart, or to analyze the total amount into some of its subgroups?" In other instances they may readily see that they are confronted with the problem of comparing the size of two groups.

It is true that boys and girls will continue to perform the fundamental operations as they are now known. They will perform them in relationship to the action implied in the problem with which they are confronted. They will come to learn that there is more than one way to group quantities together. They might either count, add, or multiply depending upon the particular situation with which they are confronted, and will also learn that under certain circumstances one or the other operation tends to be more efficient.

The content of the arithmetic program should deal much more with the history of numbers than is generally found in most of our school programs. This does not mean lock-stepping children through the history of the development of our number system for this would be an unrealistic demand. One should not expect them to be able to call up certain historical dates or facts, but to the extent that points of historical interest can be they should be introduced. In most of our schools children learn to read and write Roman numerals in the middle grades. Too often this is all that happens—they learn to read and write Roman numerals. Wouldn't it be a lot more interesting if, when they were writing Roman numerals, they were helped to understand that the Roman number ideas were similar to ours but they used different symbols to represent their ideas? Wouldn't it be valuable for

them to know that the reason our system is so much more efficient than the Romans is that the Romans could not perform the operations using only their symbols but had to translate what the symbols said to a counter in order to perform certain operations?

At a very early grade boys and girls start to learn about face value and place value of numbers as they are written. They learn about the units column, the tens column, the hundreds column, the concept of collecting into larger and larger groups. In the upper elementary grades they learn about the 1/10s column, the 1/000s column, etc. Shouldn't boys and girls know that in the history of the development of notation the extension of place value to the right of the units column is rather a recent innovation? Are they not entitled to know that boys and girls in our early American colonies were denied this opportunity in working with numbers, for it was only a few years before the first colony was settled that this idea was espoused?

There is a new approach to the solution of a long division example. Is it so unusual to develop a new algorismic form for long division? Most of our grandfathers did not record a long division algorism in the same form now commonly used. And it is not so unusual that the boys and girls in school today should learn to record it in still another way.

To the extent that items of historical interest can be brought into the program they should be. Only a few examples have been cited. Children will come to see that arithmetic is an alive and growing body of knowledge and operations. They should see that mathematical knowledge and use has actually grown right along with the history of a society.

Children need to see the interrelatedness of all mathematical operations. Interrelatedness begins with the concept of counting and the nature of recording number, then to the methods that we use for grouping and regrouping numbers in the various operations. They must come to see number ideas and their use as a tool and a skill. They should also come to recognize the value of mathematics in developing a way of thinking.

Threaded throughout the content of the arithmetic program should be the opportunity for children to apply their new knowledge and skills to solving problems which are meaningful to them and in analyzing various kinds of situations, both real and simulated, which may be developed. The final test of the learning is in whether it can be related and applied to solving certain problematic situations. It is hoped that these situations will not be the trite and threadbare variety which have often appeared in the past, but rather the type that will excite boys and girls and stretch their imagination.

Of course all of the above ideas must be developed continuously as

children proceed from kindergarten through the sixth grade. Not only must the sequential and developmental nature of mathematics be kept in mind, but also it should be remembered what is known about children and their needs. One must not overlook or avoid the information made available by those studying child growth and development.

B. *Method*

The content outlined above suggests an approach to the method which most likely should be followed. It lends itself to open-ended as opposed to closed-ended types of experiences for children in the classroom. Open-ended learning experiences are the type which do not stop with the learning of a specific fact by a child. They are the type of experiences which answer some questions but raise many more questions in the minds of the children involved. They are the kinds of experiences that lead boys and girls to ask "Why?" and "How?," and encourage them to go on and seek answers to these greater and more important questions. Open-ended experiences are the kind which broaden concepts and lead to greater understandings. They awaken a greater quest for knowledge within the learner, and lead to creative thinking and effort on the part of children.

Then there are closed-ended learning experiences. This type of experience might be shown by an example of a fact which is learned or memorized. It may tend to become an end in itself. There is little opportunity for imagination to come into play in this kind of an experience. In a classroom both kinds of experiences exist and are necessary. But teachers must strive more and more to provide the kinds of experiences which are open-ended.

In any discussion of a modern approach to method in arithmetic one cannot overlook the place of concrete materials. This includes models, film and filmstrips, pictures and sketches, the chalkboard, and assorted paraphernalia. Psychologists state that learning develops along a pattern of experiencing concretely a subject and then making more and more abstract generalizations about the particular subject under consideration. This is true in the arithmetic program at all levels.

However, teachers must certainly be discriminative in their selection of the learning materials to be used in a classroom. More materials are becoming available every day. Close examination reveals a lot of this material is simply expensive junk which has little value in an arithmetic classroom. On the other hand there is a great amount of material that is most helpful insofar as arithmetical understanding is concerned. It might be wise to start with what is closest at hand, the fingers, and proceed from that point to greater and greater levels of abstraction. The Hindu-Arabic number system has a base of ten

because God happened to put ten digits on the ends of a man's arms. The number system has developed the way it has because man counted on these ten digits on the end of his arms. Therefore, can it be so terrible if boys and girls count on their fingers in order to gain new understandings in terms of counting and regrouping quantities? The only time teachers should be concerned about children counting on their fingers is when the experiences provided have not helped them grow past this very concrete stage, so that they no longer need their fingers as counters. Does it not at times seem a little foolish and inefficient to talk about providing boys and girls with straws and bottle caps with which to count rather than let them use the ten perfectly good counters on the ends of their arms?

Teaching method in every way should provide opportunity for boys and girls to find answers for themselves and make generalizations. This is true learning. When generalizations are made children come to see the greater interrelationships of all of the phases of mathematics. Even though a body of content is provided which leads in this direction, it must not be taken for granted that all children are making the proper generalizations and understand the interrelationships involved. Questioning and problems must provide both opportunities for growth and evaluation in this respect.

If creative thought is to be fostered on the part of children, opportunities must be provided for them to make discoveries for themselves. The child who is told all the answers to his questions, and who is told what to do and how to do it in his daily arithmetic assignments certainly is involved in closed-ended learning experiences. Why should he stretch his imagination, or reason for himself, if someone else does all of his thinking for him and all he has to do is memorize a few skills? Opportunities should not be overlooked for allowing a child to discover an answer for himself. And discovery is not finding out something quite by accident, but more often a continued series of experiences and opportunities leading to progressively more important discoveries as they fit together into the whole picture of the development of arithmetic.

In terms of the above statments, what place should drill or practice have in the present day program? Certainly it would not be a routine rote kind of drill. In terms of the content available and the method being followed rote drill would certainly be out of place and probably quite inefficient. Rather, children should be allowed many opportunities to practice their new found skills and understandings. This practice should not be the same for all children but would be in terms of a particular need for making facts, skills, and knowledge an automatic part of their behavior. The practice should not only be varied in terms of the amount but in kind depending upon the needs of the students

involved. But the importance of practice, after understanding, must not be overlooked. Knowledge and skills become internalized, and consequently readily available, through continued practice and use.

Arithmetical understandings are used every day by children as by adults. Methodology should be such that each child develops an appreciation for what arithmetic is, how and why it developed, and its useful potential. Insofar as possible each child should experience great satisfaction with his discoveries in the world of numbers and the way these discoveries fit together to build this very organized and useful body of knowledge.

C. *The Teacher*

It is hoped that any teacher who will be working with boys and girls in the above discussed program will have many questions about mathematics and will continually be making new discoveries for himself. He need not be a mathematician in the sense that he has sat through many formalized mathematics courses at the high school and college level but he does need a curiosity about mathematics and he does have to be able to think mathematically. If he posseses anxieties about his limited ability in the area of mathematics he must be willing to overcome these anxieties in terms of finding new answers for himself.

The best teacher is one who is willing to admit that he has not learned many of the answers himself. It is tragic for children to sit at the feet of teachers who believe they have all of the answers. It is equally as tragic for the teacher, for this is only one sign that a teacher has stopped learning and growing.

The best teacher will not try to make mathematicians of children but will rather try to provide the broad general mathematical education necessary so that the child who has the ability will want to be able to continue studying mathematics. His students will possess greater understandings in the higher levels of mathematical application and practice. He remembers that children are individuals and that it is children that are being taught mathematics. He will keep in mind the principles of child growth and development as well as the laws of learning. This teacher can make adjustments, likes to see children learn, enjoys learning more himself, and keeps a perspective on all of life.

III. Summary

Is it too idealistic to expect these elements in a good arithmetic program? One might ask, "Where do you find this kind of teacher?" or "Where is the outline of this content?" or "Who has time to follow this method?" But this kind of teacher does exist and by encour-

aging freedom in teaching and allowing teachers to make discoveries for themselves, more and more such teachers will become apparent.

The method is simply that which has been followed by good teachers for many years. But it is not the method followed by teachers who are simply dispensers of knowledge. Dispensers of knowledge too often provide only closed-ended learning experiences. This is also not the method that would be used by a teacher who is an autocrat in the classroom. Most teachers realize that they command greater respect by guiding boys and girls to deeper insights rather than telling or showing them what they have to know or do.

The content outlined above is found in almost every modern series of arithmetic textbooks. It may not be laid out exactly this way, but the framework is there. It is up to the person who is acting as the guide in the classroom to help boys and girls interpret this framework and to see the pattern that exists. If the arithmetic book becomes the curriculum and each day's lesson becomes an end unto inself, certainly arithmetic will never be seen by children in its true perspective. It is up to the teacher to build onto the framework provided and to tie the program together in terms of overall and long-range objectives. It is up to each teacher to provide greater opportunities and experiences so that the proper insights are developed.

This program does not provide the opportunity for first grade children to learn to multiply a two place number by a two place number. It does not provide that second grade children shall be taught geometry, and it does not accept that all of the arithmetical understandings can be taught by building an arithmetic program around the use of an abacus.

It is evident that children in the first grade can learn to multiply, those in the second grade can learn much geometry, and a lot of mathematics can be taught with an abacus. Children are amazing in terms of their learning ability. But why, in the name of arithmetic, must such unrealistic demands be placed upon a child's time and ability. The Romans needed an abacus to compute, but it is only one of many aids available today. What child needs to know geometry at the second grade level, or how to multiply at the first grade level? Many questions must be raised and answered before some arithmetic programs become acceptable.

Would time and effort not be better spent in providing a very sound mathematical program which is continuous and sequential in terms of all children's needs and in terms of greater insights into our particular number system? And do we not have evidence that boys and girls best learn through a variety of materials and a variety of approaches leading to particular understandings? Each teacher must attempt to do a

better job and a more thorough job of teaching arithmetical understandings and the nature of our number system. But acceptance of this challenge does not license an educator to disregard either the needs of children or the nature of mathematics. Likewise, the depressing of upper level fields of mathematical specialization further into the elementary curriculum must be stopped. There are too many other necessary and worthwhile understandings which should be developed.

MICHIGAN COUNCIL OF TEACHERS OF MATHEMATICS

The 12th annual conference of the Michigan Council of Teachers of Mathematics will be held at the M.E.A. camp, Saint Mary's Lake, Battle Creek, on May 5, 6, & 7, 1961.

Inquiries should be addressed to Mrs. Marjorie Pickering 5198 Coldspring at Birmingham, Michigan.

STUDY VIRUS GROWTH PROCESSES UNDER ELECTRON MICROSCOPE

What appears to be the growth processes of viruses within a cell—from naked threads of nucleic acid to "full-clothed" rod-like viruses—has been revealed by electron microscope studies.

Drs. John M. Adams and David T. Imagawa of the University of California Medical School at Los Angeles, with Dr. J. R. Goodman of the Long Beach Veterans Administration Hospital Research Laboratories, studied three related viruses—measles, distemper and rinder-pest.

When these, as well as other viruses, attack a living cell, new objects called inclusion bodies appear in the cell nucleus and cytoplasm.

The UCLA investigators examined these inclusion bodies, which have a characteristic pattern in cells invaded by each of the viruses, under the powerful electron microscope.

In certain stages of development, the pattern is one of randomly arrayed thread-like strands or filaments. In other stages, it is one of closely packed rods.

This evidence suggests that inclusion bodies are clumps of viruses reproduced in the infected cell. The thread-like strands may be the immature virus, which consists only of its nucleic acid core. The dense rod-like pattern may represent clumps of mature or nearly mature viruses that have added a protein coat to their nucleic acid core.

The UCLA scientists said this technique of studying the virus within the infected cell may contribute valuable information to the knowledge of the "life history" of viruses. Other virus researchers have employed chemical and centrifuge procedures of extracting the virus from the cell and then studying it by electron microscopy.

The Gentle Art of Problem Solving

Sister M. Stephanie Sloyan

Georgian Court College, Lakewood, New Jersey

Problem solving is an art. Skills are important, basic procedures must be understood, but in the final analysis the solving of a mathematical problem one has not seen before depends upon a happy inspiration, or the putting together of hitherto disparate elements, and demands the same kind of creativity and imagination as the fashioning of a particularly apt metaphor. Furthermore, the thrill of solution is of the same order as that received from the production of a perfect short story.

But the purpose of this paper is not to praise problem solving (or problem solvers), but to speak of a special kind of problem solving as a valuable adjunct to teaching mathematics. By problem solving I mean the solution by students, on all levels, as part of their course work, of problems published in mathematical journals, and the publication of the students' solutions.

Problems are of all degrees of difficulty, from the simpler ones in the *Mathematics Student Journal* to the Advanced Problems in the *American Mathematical Monthly*. There is, for example, the problem department in this journal, SCHOOL SCIENCE AND MATHEMATICS, edited by Margaret F. Willerding, containing many problems within the ability of high school students, and all within the ability of college students. Students who submit correct solutions are listed in a special honor roll and receive an issue of the magazine in which their correct solution appears. The Elementary Problem department (edited by Howard Eves) in the *American Mathematical Monthly* (with problems sometimes not so elementary), and the Advanced Problems (edited by E. P. Starke) in the same periodical, contain problems in all fields. The *Mathematics Magazine* for years has had an excellent problem department. If one desires problems in geometry and number theory, the Belgian journal *Mathesis* has an admirable collection in each issue.

Of course the student can and must solve problems from his text. He does this all through high school and all through college, and without this type of problem solving there is no learning. Mathematics is not a spectator sport. One cannot learn mathematics without actively taking part. But even if there is active participation on the part of the learner, the working of textbook problems is usually regarded as labor. We are writing about problems for enjoyment, with learning as a by-product.

If the college student, or even the more advanced high school student, has access to the problems appearing in the journals each

month, and faithfully attempts their solution, even if he succeeds only occasionally, he is keeping in touch with the work being done by mathematicians (for some of the problems proposed arise in connection with research). He learns to apply all the techniques he has acquired in various courses, and, most important, he has the thrill of discovering for himself, almost as if he were responsible for a new theorem. He is engaged in activity which, *for him*, is original. He can learn to generalize. He can be encouraged to go on from the solution he has obtained to question further, "What would happen if . . . ?" In this way he may be led to discover something truly new.

Some people have made mathematics a career after becoming interested through solving problems. There is evidence that a large number of research papers and theses for college degrees have had their origin in the *American Mathematical Monthly* problem department.[1] For two hundred fifty-one of the problems published in the *Monthly* between 1918–1951 no solutions have been received. These may be used as a basis for research.

Finally, if the student is successful with his problem, he should attempt to publish the results. In this way he will learn to submit solutions in the most acceptable form, logical and succinct. Various pieces of advice have been offered by editors to would-be authors of solutions. "He [i.e., the editor] may hope that the solution will not leave too much to be desired in organization, grammatical structure and legibility."[2] And from *Mathesis*, this: It is necessary to be at the same time clear, precise, and concise.[3] The student will learn that if his solution is correct, but either wordy or elliptical, it will not appear. Let him strive to be the one whose solution is the most elegant so that it will be published. While the discovery of a correct solution should be reward enough, it helps the student's morale to see his solution, with his name attached, in the pages of a national magazine. Someone has said that the desire to see one's name in print is the last small vanity to disappear! Aside from this, since all scientists and mathematicians are encouraged to publish and share their discoveries with others, such publication by the student can be an excellent beginning.

Sometimes the current problems fit well with work being done by a particular class. More frequently they do not. In this latter case, one of two things may be done. The instructor may suggest problems from previous issues of the journals which are appropriate. If solutions have been published in the meantime, the student can compare his own for elegance and simplicity; he may find an alternate and better solution. In the cases where no solution has ever been received the student is in fact attempting a "current" problem and his solution is still publishable material. On the other hand, instead of searching

for problems appropriate to a particular subject or lesson, let the instructor suggest interesting problems which may have no bearing on the daily work, but have value in themselves for the material they contain.

In the foregoing paragraph, I have been careful to use the word "suggest," rather than "assign," as the work of the instructor. These problems are not a task to be performed. They should become something that the student wants to do, on his own time and for his own pleasure, and not something to be counted in with a grade point average. With an inspiring instructor who makes frequent reference to such problems, pointing out ones that are important to the student at this stage of his mathematical development, the student should look forward to forthcoming issues of the periodical, and should find it almost impossible to refrain from turning to the problem page first.

References

1. The Otto Dunkel Memorial Problem Book, supplement to *American Mathematical Monthly*, 64: 7, 10.
2. *Op. cit.*, 6.
3. *Mathesis*, LXIX-6, back cover.

COMPOUNDS OF "DINOSAUR" ELEMENT 98 PREPARED

The first pure compounds of the man-made element californium, no. 98, have been prepared by scientists at the Lawrence Radiation Laboratory of the University of California, Berkeley, where this element was first made.

Three separate californium compounds—californium trichloride, californium oxychloride and californium oxide—were prepared by treatment of the element with hydrochloric acid and steam at high temperatures.

The feat of carrying out indentifiable chemical reactions with such minute quantities of material—samples weighing about a ten-millionth of a gram—was accomplished as a result of the recent perfection of techniques for working on the "submicrogram" scale.

Californium is one of the "dianosaurs" of matter—an element that may have been present in the beginnings of the earth but soon disappeared through radioactive decay. The element was first fabricated with the use of the atom smashers by University of California scientists.

FUTURE SATELLITES MAY BE COOLED BY HOT COATING

A burning coating may cool satellites of the future during re-entry into the earth's atmosphere. Dr. Andrew F. Charwat, professor of engineering at the University of California, Los Angeles, said. The reason:

During re-entry, the surface of a high-speed missile or satellite heats up to 5,000 to 10,000 degrees Fahrenheit, which would burn both men and instruments. This tremendous heat can be reduced, however, by coating the surface with a solid material that will either ablate (melt) or sublimate (evaporate) during re-entry.

A good sublimating material like graphite carbon, or instance, will burn up during re-entry, but in the process will absorb and evaporate enough heat to lower the missile's surface temperature from thousands of degrees Fahrenheit to a few hundred degrees.

Reactions of Scientists and Science Teachers to Statements Bearing on Certian Aspects of Science and Science Teaching*

Frances L. Behnke

245 W. 101, New York 25, N. Y.

The upsurge in public interest in science and science teaching since World War II has revealed some disquieting misunderstandings about the nature of science and science teaching among citizens in all walks of life. The calm needed to discuss publicly the issues involved is difficult to maintain in the face of the cold war and the alleged Russian advances in science and technology. Complicating the situation further is the widespread assumption that a vigorous and advancing science and technology are absolutely essential for the preservation of our American way of life. It is not surprising, then, that the scientists and the science teachers have emerged as central figures in this period of anxiety and uncertainty.

The main purpose of the study, partially reported here, was to survey, by means of a mailed questionnaire, the opinions of a selected group of high school science teachers and a small group of scientists with respect to certain issues and apparent public beliefs about science in American life. The data gathered were analyzed to determine certain differentials implied in the following questions:

1. Are there significant differences between a select group of science teachers and scientists with respect to their opinions on certain aspects of science and science teaching?
2. Are there differences of opinion on science and science teaching between selected groups of physical science and biology teachers?
3. Do teachers from different geographical regions differ in their opinions about science and science teaching?
4. Are there variations in the opinions of science teachers as a result of differences in educational background and teaching experience?

The possible importance of this study rests on the assumption that the opinions and attitudes of science teachers toward science and its relation to American life directly and significantly influence the quality of science teaching. If it could be shown that many science teachers express opinions or attitudes which indicate misunderstandings, even misconceptions, about the nature of science, then we face a problem of the first magnitude in the training of science teachers. It may well be that disclosures of recent studies on the apparent nonconstructive attitudes of young people toward science can be traced in part to the science classroom.

In any case, a modest probing of the thinking of science teachers

* This article is based on an unpublished doctoral study, Teachers College, Columbia University under the auspices of the Science Manpower Project.

about certain aspects of science might reveal data which would furnish guidance for constructive proposals aimed at improving the teaching of science.

The Survey Instrument

Of the several techniques available for surveying or probing the opinions and attitudes of a selected population, a modified questionnaire was deemed most practical in the light of the purposes of the study and available resources for carrying it out. A questionnaire containing fifty statements was prepared to obtain responses from two populations on certain issues. The populations were a selected group of scientists and science teachers. The responses were registered as favoring, opposing or taking a neutral position on the selected items.

Many sources were used in developing the statements such as articles written by scientists on various issues, scientific and philosophical literature, personal observations, discussions in conferences and classes, and exploratory interviews with a variety of specialists. To insure adequate coverage and balance, four categories of statements were developed:

A. The nature of science: statements on the character, importance and limitations of science.
B. Science and society: statements on the relation of science to the social order.
C. The scientist and society: statements on the role and place of scientists in society.
D. The teaching of science.

In order to eliminate unsatisfactory questions in each category, the statements were pretested on various pilot groups such as high school science teachers and participants in a conference on science and religion.

To investigate possible differentials among science teachers with respect to their reponses to the items in the questionnaire, certain personal data were requested. They were asked about their educational background, number of years of teaching experience, subjects taught, type of undergraduate and graduate institution attended and number of credit hours earned in science and in education.

The Population Studied

One thousand physical science and biology teachers from the membership rolls of the National Science Teachers Association were used as the sample for the teaching group. Cards for the entire membership of NSTA were arranged alphabetically by states, and the states were then grouped in three geographical regions: the Northeast, the South, the West-Midwest. The ratio of biology to physical science teachers in the membership was two to three, and therefore, 400 biology and 600

physical science teachers were chosen. The individual teachers were selected by random number techniques.

The scientists were limited to 100 chosen from a list furnished by the Director of the Science Teaching Improvement Program of the American Association for the Advancement of Science and from lists suggested by those familiar with scientists prominent in both the academic world and the national scene. The scientists were from all geographical areas of the United States. Twenty-eight were actively interested in science education and 72 in research, academic life, or public affairs. Fifty-two could be classified as working in the field of the life sciences and 48 in the physical sciences. Seven were in research institutes, foundations or government service, and the rest held academic positions. Seventy of the 100 scientists responded to the questionnaire.

Of the 1000 questionnaires sent to science teachers, 621 or 62% were returned, with 200 or 50% from biology teachers and 421 or 71% from the physical science group. To find out whether the responses were representative of the stratified random sample, a second mailing was sent to a group selected from those who failed to respond to the first mailing. Seventy-one percent of this group replied. Responses of the first and second groups were compared and Chi square values were calculated to see whether the differences were accidental or arose through sampling variations. The differences in replies of the two groups were minor, and it was assumed that the responses received were reasonably representative of the total sample.

Treatment of the Data

The responses to each item or statement were converted to percentages of agreement, disagreement or neutrality. The percentages were calculated, using as a denominator the actual number of responses which, in some few cases, varied slightly from the total number of teachers or scientists who returned questionnaires. Analyses were made under the four categories. First, the responses of the total teaching group were compared with those of the scientists. The teachers were then divided into five subgroups: subject taught, geographical region, type of undergraduate institution attended, ratio of hours in science to hours in education, and length of teaching experience. An item to item comparison was made for each sub-group. To test the significance of the difference between the percentage responses, the standard error of difference between two uncorrelated percentages was calculated. Critical ratios were obtained and levels of confidence established. Some of the more interesting findings are summarized in terms of the established content categories and the various groups compared.

Scientists and Science Teachers

The responses of the science teachers and scientists to the items included in the four categories were summarized as percentages of agreement, disagreement and neutrality and then compared on an item to item basis.

On the Nature of Science

The fourteen statements in this category were designed to evoke responses which would give some indication of each respondent's understanding of the nature of science and the scientific enterprise. The statements dealt with such matters as the value of team research, the limitations of science, goals of scientific work, the scope of scientific approaches to everyday problems, and the tentativeness of scientific findings.

The item to item comparison of the responses of the scientists and the teacher was revealing. On five of the statements agreement between the two groups was fairly close. A slight majority of both scientists and teachers seemed to feel that team research was more productive than individual research. On the question of the limitations of science, both groups recognized that there were limits but rejected the idea that certain investigations should be limited on account of the possible bias of the investigator. The responses on these points were understandable since the scientific approach does have limitations at present and it is possible to recognize the limits of the scientific approach without specifying a biased investigator as an inevitable feature of these limitations.

On the question of the goals of scientific work, only twenty percent of the scientists believed that the goal of scientific work was the improvement of human welfare or the solving of practical problems. Over 50 percent of the teachers thought otherwise. Consistency of response on these two items was noted for both scientists and science teachers.

The scientists were more inclined than the teachers to reject the idea that it is unnecessary to use scientific procedures to establish man's place in the universe. The fact that almost one fourth of the scientists and one third of the teachers either agreed with this statement or were neutral was somewhat surprising in that scientific procedures have already been used extensively for this purpose.

The statement that belief in an orthodox religion would interfere with the work of a scientist brought disagreement on the part of a large percentage of the science teachers. Only a small percent were neutral on this point. A smaller majority of the scientists also rejected the statement; only 14 percent agreed. Because it is unlikely that many science teachers have faced this problem directly, they seemed

more optimistic about the ability of a human being to compartmentalize his beliefs and opinions.

Although it is true that there are many dependable facts in science, it is generally agreed that its findings are tentative and absolute certainty is not a characteristic goal of the scientific enterprise. It was surprising that over one half of the teachers felt that scientific findings were not tentative. Even more surprising was the 20 percent of the scientists who felt the same way. That there may be some confusion on this point was indicated by a comment volunteered by a teacher:

> "Science is 'plagued' by the uncertainty principle. Math is loaded with absolutes."

A higher percentage of scientists than teachers disagreed with the oft-quoted assertion that a scientist may help to achieve a desired value but he cannot help in the selection of this value. It should be noted that almost one fourth of the scientists and teachers failed to respond positively or negatively to the statement. One scientist commented:

> "The scientist must accept stated values but he may help the public deal more effectively with values by describing, explaining, clarifying, or predicting the outcomes of certain values."

The relation of high intelligence to the making of a superior scientist was recognized by a large majority of the scientists. On the other hand hardly more than half of the teachers agreed that to become a superior scientist requires superior intelligence. It may well be that this indicated a basic difference in point of view toward intellectual achievement between the two groups.

In summary, statements which were phrased from a sociological point of view or approached the nature of science indirectly, evoked responses on which the two groups were in closer agreement than statements which dealt directly with specific aspects of the nature of science. The statements which produced the most marked differences between the scientists and the teachers were those about the goals and limitations of science. The point of view of the teachers toward the goals and limitations may reflect the general public attitude and misunderstanding of these important aspects of science. This was apparently not true of the scientists to the same extent. In any case it may be said that on statements which involve an understanding of the scientific enterprise in some depth, the teachers differed most from the scientists.

On Science and Society

Of the fifteen statements in this category, four pertained to the extension of the scientific approach to the solution of human prob-

lems; five to the impact of science on society, and six to the impact of society on science.

Both the scientists and the teachers were apparently optimistic about the use of the scientific approach in the solution of human problems, the science teachers more so than the scientists. Statements referring to the impact of science on society evoked responses which produced the greatest differences in this category. Over one half of the scientists agreed that man's religious doctrines should be continually revised in the light of new scientific truths; only one fourth of the teachers agreed.

With one exception, responses to the statements pertaining to the impact of society on science showed little difference between the two groups. To a greater extent than the teachers, the scientists felt that the use of scientific evidence to justify religious, economic and political dogma was harmful to the development of social institutions. Both the scientists and teachers were in strong agreement on the necessity of public understanding of science, and that the public's point of view toward science was based largely on acquaintance with technology. On the question of the hostility of the socio-political environment to the development of scientific talent, less than one third of both groups agreed, nearly one half disagreed, and the rest were neutral.

On the Scientist and Society

There was little difference between the scientists and the teachers on items pertaining to the participation of the scientists in public affairs. Both groups were almost unanimous in favoring the participation of the scientists in creating better public understanding of their work, and in helping to formulate public policy on matters related to the scientific and technological enterprises. Both were in high agreement that the scientist should be concerned with the social effects of the discoveries he has made and about three fourths of both groups felt that the control over the use of scientific discoveries should not be solely in the hands of non-scientists.

The most marked difference was evoked by the statement which asserted that the scientist should conform to social pressures. Here 80% of the scientists and only 4% of the science teachers agreed to this statement. Yet only 30% of the scientists and teachers agreed that our society should expect the scientist to abandon his work when asked by the government to do something for the public welfare.

It seems apparent from their responses that the scientists as a group were denying the validity of the "ivory tower" position. With the exception of the item on resisting social pressures, the teachers, too, felt that the scientists should be active in public issues bearing on the scientific enterprise. The marked difference between the two

groups on the question of the conformity of the scientist to social pressures is difficult to account for in the light of the responses to other statements in this category. It may be that the scientists participating in this study were anxious about their status as citizens, and the teachers were thinking of pressures they themselves had to deal with in their local situations and were expressing their strong disapproval. It seems unlikely that 80% of American scientists would agree to this item if it were interpreted as infringing on their autonomy as scientists.

On the Teaching of Science

On several statements related to what to teach and how to teach it, there was close agreement between the scientists and the science teachers. On statements which involved social issues of scientific origin, the two groups differed markedly. In these instances it is likely that the scientists responded more from a purely scientific point of view than the teachers who seemed more inclined to base their opinions on human welfare considerations.

Both groups were nearly unanimous in rejecting the assertions that the scientific facts about human reproduction should not be taught and that mention of Russian contributions to science should be avoided in high school science classes. On the question of teaching high school science in terms of strict cause and effect relations, a significant majority of teachers and a smaller majority of the scientists disapproved. The introduction of moral issues into science teaching was approved by a much larger percentage of the teachers than scientists. Apparently the scientists were more fearful than the teachers of the distorting influence of science fiction on a student's outlook on science, and were less optimistic than the teachers on the value of research related to educational work. Voluntary comments by a few scientists expressed skepticism of the possibility and value of educational research.

The two statements in this category which showed the largest differences pertained to special provisions for those with exceptional talent and to the competency of a teacher to teach biology who rejected evolutionary concepts. Only one fourth of the scientists agreed and more than one half disagreed that it is undemocratic to make special provisions for those with exceptional scientific talents. On the other hand, almost all the teachers rejected this assertion. That so many of the scientists should view this proposal as undemocratic may well be a consequence of their misunderstanding of the intent of the statement.

Teachers and scientists disagreed rather sharply on the statement about the competency of a biology teacher who rejected evolutionary

theory. The great majority of the scientists thought that such teachers were not qualified to teach biology while only a third of the teachers agreed. That the issues involved in this statement are many and deeply rooted in our culture was admitted without question; yet, it is difficult to see how biology could be represented as a science without the modern theories on evolution. There was the possibility that many of the teachers included in the study did not believe in evolution in any guise.

Summary

Responses to statements included in the category *On the Nature of Science* discriminated between the groups more than statements in the other categories. It seems clear that much of the misunderstandings and many of the apparent inconsistencies noted were related to a lack of understanding of the nature of science. To the investigator it seems unlikely that clarity on issues raised by the statements in the questionnaire will come about unless there is an increase in knowledge and understanding of the nature of the scientific enterprise on the part of both teachers and scientists.

Intragroup Comparisons of the Responses of the Science Teachers

After the opinions of the science teachers were compared with those of the scientists, the data from the teachers were analyzed to determine intragroup differences with respect to subject taught, regional location of school, and type of educational background. Five subgroups were established and item by item comparisons were made. There was no attempt to draw a composite picture of the precise views and opinions teachers should hold on the selected issues and aspects of science. The purpose of the comparisons was to reveal differences which might exist among the teachers' responses in the sub-groups established.

Physical Science and Biology Teachers

As indicated earlier, 421 physical science and 200 biology teachers returned completed questionnaires. The item by item analysis of the fifty statements in the survey revealed relatively little differences in the responses between teachers in the two subject matter fields. There were only five items for which there was a significant difference at the .01 level of confidence. Of these five items, three pertained to the nature of science and two to the teaching of science.

Eighteen of the items showing the greatest differences between the opinions of scientists and the total teaching group were examined with respect to the physical science and biology teachers. In general

the physical science teachers agreed more closely with the responses of the scientists than did the biology teachers. However the differences between the two sub-groups and the scientists were small except for the responses to the items dealing with the acceptance of evolutionary theory as a prerequisite for a biology teacher. Here, the physical science teachers were significantly closer to the scientists than the biology subgroup.

The two groups were closer to agreement with each other than either group was with the scientists. Evident in the responses was a homogeneity in opinions of the teaching groups that seemed to transcend the division into teaching fields.

Geographical Differential

To determine whether the opinions of the science teachers varied according to the geographical location of their teaching positions, the total group was separated into three geographical regions: 176 teachers from the Northeast; 111 from the South; and 334 teachers in the West-Midwest group.

In the analysis, 17 statements were found to indicate significant differences about the three sub-groups. Seven of these pertained to the nature of science, five to science and society, four to the teaching of science, and one to the scientist and society. To a greater degree than was true for the other two sub-groups, the teachers from the Northeast felt that scientific procedures were needed to establish man's place in the universe; that the practical was not an important emphasis of the scientific enterprise; that the improvement of human welfare was not a primary objective of the working scientist; and that superior intelligence was necessary to become a superior scientist. On the teaching of evolution, the teachers from the South showed the lowest percentage of agreement; a teacher who rejected evolutionary theory should not teach biology. The teachers from the West-Midwest had the highest percentage agreement (of these sub-groups) on this item.

The responses of the teachers from the Northeast, when taken as a group, suggested a somewhat greater degree of sophistication than the other two subgroups in that they were in closer agreement to the responses of the scientists and to what the investigator judged to be constructive responses, especially on items pertaining to the nature of science. The differences among the subgroups was not marked and the similarities outweighed the dissimilarities. The differences were less marked than those between the scientists and the total teaching group. Responses of the teachers from the West-Midwest were closer to the Northeast than were the responses of teachers from the South. Those from the South tended to be more optimistic on questions involving the extension of the scientific approach to the solution of

human problems including values, and to consider the goals of science more in terms of practical outcomes and human welfare than either of the other sub-groups.

Number of Science and Education Courses

The number of semester hours in science and education reported by the teachers on the front page of the survey instrument were totaled, and three subgroups were established based on the ratio of hours in science to hours in education; both graduate and undergraduate credits were combined in the totals. Sub-group I included teachers with approximately twice as many hours in science as in education; sub-group II those with approximately equal numbers of hours in science and education; and sub-group III those with approximately twice as many hours in education as in science. The number of teachers in sub-group I totaled 336; in sub-group II, 176; and 49 teachers in sub-group III. The ratios of hours in science to hours in education were taken as three points on a continuum with the number of hours in science ranging from 5 to 196 and in education from 0–140.

The distribution of course credits in science and education reported by 561 teachers did not support the comment frequently made that science teachers take so many courses in education that they have no time for the study of science. Almost 60% of the teachers in the study reported approximately twice as many hours in science as education while less than 9 percent reported the converse. Many of the courses labeled education may have been courses that dealt with scientific materials.

When the percentage responses of these three sub-groups were compared on the fifty statements, the differences among the teachers with varying course credits in science and education were not as great as was expected. Some comments on the responses of the small group of teachers with the least science credits may be interesting. Among the three sub-groups, they had the highest percentage disagreement on the question of teaching science in the high school in terms of strict cause and effect relationships and the lowest percentage agreement on the issue of whether or not a teacher who rejects evolutionary theory should be permitted to teach biology in the high school. They were the highest in percentage disagreement on the statement that a scientist should conform to social pressures, and on the statement that the scientist should abandon work he wants to do when asked to do something for the public welfare. They were less fearful of the detrimental effect of science fiction on the young than the other two sub-groups; in greater agreement that a primary object of scientific work is the improvement of human welfare, and in lesser agreement on the question of the greater productivity of team over individual scientific research.

Differences among the three sub-groups were, on the whole, less than the differences between the scientists and the total teacher group. As might be expected, the sub-group with the most science background responded to the statements in a manner closer to the scientists than was the case with the other two groups although there were exceptions. The sub-group with the least science background was, in general, furthest from the scientists in their responses. This should not be interpreted to mean that one group is more correct than the other, for such an evaluation was not an objective of this study.

Type of Institution of Higher Education Attended

Teachers responding to the questionnaire were asked to list the educational institutions where they took their undergraduate and graduate work. On the basis of these data, the teachers were separated into three sub-groups: a sub-group of 259 teachers who graduated from liberal arts colleges; a sub-group of 221 teachers who graduated from universities, and a sub-group of 121 teachers who graduated from teachers colleges.

When the responses of the three sub-groups to the fifty statements were compared it was found that the differences were less than among any of the sub-groups compared in the study. There was practically no significant difference between the liberal arts and university sub-groups. The teachers college group differed most from the other two sub-groups. This may be misleading since the majority of the responses did not show percentage differences that were considered significant. When the responses of these sub-groups were compared to the responses of the scientists, little difference was found among the sub-groups.

Teaching Experience

Data on years of teaching experience secured from the teachers in the study were used to establish two sub-groups at the extremes: those with five or less years and those with twenty or more years of teaching experience. There were 142 teachers in the first sub-group and 162 in the second. The teachers with the greatest amount of experience differed most markedly from those with the least on the question of teaching evolution; a teacher who rejects evolutionary theory is not qualified to teach biology. Not only did they show a higher percentage agreement on this item than teachers with the least experience but also their percentage agreement was higher than for any of the sub-groups in this study.

On the question of teaching science in terms of strict causal relations, and on the statement concerning the possible ill effects of science fiction on young people, the teachers with the least experience

disagreed more than older teachers. They were also more inclined to favor the introduction of moral issues in the teaching of science. The more experienced teachers were in greater agreement that it takes superior intelligence to become a superior scientist; that team research is more productive than individual research; that the use of the scientific approach will help man in his personal problems; and that there should be widespread acceptance of the scientific approach to questions of value. It is interesting to note that statements pertaining to the nature of science were less effective in discriminating between these groups than was true for the other sub-groups.

Summary

For all the sub-groups compared, and when all the data obtained were taken into account, it was concluded that in general the significant differences among the various sub-groups were very much fewer than the similarities. When the comparisons among the sub-groups were compared with the comparisons made between the scientists and the teachers as a group, it was found that in general the differences among the teachers were less marked than those between the scientists and the teachers.

The most effective category for discriminating among the sub-groups was *The Nature of Science.* The discriminating power of the items in this category was demonstrated in all the comparisons made among the sub-groups except those involving length of teaching experience.

A hypothetical composite teacher who embodied the differences found among the sub-groups was suggested by the results of the analyses. He would be a physical science teacher from the Northeast who graduated from a university or liberal arts college with twice as many course credits in science as in education and who had had 0–5 years teaching experience.

Education of Science Teachers

Earlier in this study it was pointed out that the science teacher is the key element in any science program and that his attitudes and opinions toward science and science teaching influence the effectiveness and validity of his work. Furthermore, it was assumed that if approximations of opinions on certain aspects and issues of science and science teaching could be obtained, clues would emerge which would enable the investigator to formulate suggestions for the improvement of programs for the training of science teachers. It is believed that clues were found, and their implications for teacher education are discussed below.

Central elements in the understanding of the scientific enterprise

are the recognized goals and limitations of science. Over one half of the teachers but only one fifth of the scientists felt that the goals of science were practical and aimed primarily at the improvement of human welfare. What seems to be at issue here is the status of the long-established goal of scientific endeavor—to increase man's stock of dependable knowledge about himself and his universe, and its relation to the practical and to human welfare. In a sense it may be argued that sooner or later all scientific findings have practical applications and that an increase in knowledge is, of itself, a contribution to human welfare. To assume this point of view without qualification, however, seems to this investigator to misrepresent the nature of scientific work and the goals which guide the scientific enterprise. The history of science seems to show that there is no necessary one-to-one correspondence between a preconceived practical application and a basic scientific development.

The tentativeness, and the absence of absolute certainty which characterize scientific findings were thought by this investigator to be well established. Yet more than one half of the teachers disagreed or expressed neutrality. The fact that only 49% agreed strongly suggests that there are many science teachers who view the substantive content of science as fixed and unchangeable. Such an authoritarian view of science is, of course, not justified and would certainly lead to a misrepresentation of the sources of authority of science if it prevailed in a teaching situation.

The reactions of the teachers on the points discussed above and their reactions to questions on the limitations of science suggest possible improvements in the education of science teachers. First, prospective science teachers should have the opportunity to acquire a comprehensive understanding of the nature of the scientific endeavor, including its goals, limitations, and relation to other ways of thinking and working. For the prospective science teacher to achieve this goal, it will be necessary to provide opportunity for him to investigate studies in the history and philosophy of science. Such opportunities may be provided in at least two ways: first, in regular science courses; and second, in a special seminar.

In the substantive science courses, it should be possible to incorporate a number of problems related to the nature of science, its goals and limitations, which would draw on authentic materials from the history and philosophy of science. In addition, it is strongly recommended that the program of every prospective science teacher include a one semester senior seminar on the history and philosophy of science. Here it should be possible to achieve an understanding of the evolution of scientific thought and thus gain appreciation of science as an intellectual endeavor of the greatest importance in modern socie-

ties. Widespread public understanding of the nature of scientific endeavor is essential for a healthy society. The science teacher, wherever he may work in the educational enterprise, is in a strategic position to further this understanding, provided he possesses it himself.

The teachers indicated in their responses a rather optimistic view on the value of the scientific approach to the solution of social and personal problems. Paradoxically, about one half of the teachers felt that science cannot aid in the selection among possible values. On responses to statements pertaining to the impact of science on society and vice versa, the great majority of teachers felt that man's religious doctrines should not be revised in the light of new scientific findings and that the use of scientific evidence to justify religious, economic, and political dogmas was not harmful to the development of social institutions. About one half thought that the socio-political atmosphere of the United States was not hostile to the development of scientific talent. Almost all the teachers rejected the assertion that scientists should conform to social pressures. On the other hand, the teachers thought that scientists should work for public understanding of their efforts and that they should be concerned about the social effects of the discoveries they have made.

The responses of the teachers to the selected statements summarized above suggested to this investigator the need to provide in the training programs for science teachers studies in the sociology of science. These studies should deal as directly as possible with such problems as the status of scientists in our society, the need for autonomy in the scientific enterprise, and the influence of society on science and vice versa. Also, the work required of prospective science teachers in the social studies should be reorganized so as to include a considerable emphasis on science as a social institution and on the social impact of science and technology, particularly their influence on religious, economic, and political institutions.

The analysis of the responses of the teachers to statements pertaining to the teaching of science revealed some interesting problems of importance in the training of science teachers. Almost 40% of the teachers agreed or were neutral on the proposition that high school science should be taught in terms of strict cause and effect relations. Only about one third of the teachers agreed that a teacher who finds it impossible to accept evolutionary theory is not qualified to teach high school biology.

In view of these and similar responses it seems reasonable to suggest that all prospective science teachers should have ample opportunity to study modern aspects of science, including the most recent developments in theory or conceptual schemes. In addition, time and appro-

priate resources should be made available to encourage and help the teacher-in-training to explore and examine critically the significance of the conceptual schemes or theories which characterize a given science. Further, the cultural ramifications of modern scientific theories should be explored with teachers, and problems arising from them should be thoroughly examined for their significance for teaching. Here it would be important to relate studies in the history and philosophy of science in order that teachers could have an opportunity to think about such issues as are implied in the two statements mentioned above in a proper philosophical and historical context.

The responses of the teachers to the statement on educational classroom research clearly indicate a desire on their part to carry on research activities pertinent to their work as teachers. This is a very important point, for it is believed that science education would be greatly improved if more teachers were able to test new ideas and new programs in their own classroom situations in an organized and systematic fashion. Prospective science teachers should have an opportunity to acquire the skills, knowledge and insight needed to carry on small-scale research with small groups in an action situation.

Further Studies Needed

There can be no question that the science teacher has a pivotal role as an interpreter and clarifier in his teaching field, particularly with reference to science as an intellectual activity and its influence on other intellectual endeavor. Further, it is highly likely that the personality of the teacher has a fundamental bearing on his effectiveness as a teacher, for it is clear that the science teacher's outlook on life in general may or may not be compatible with the scientific outlook. There is no doubt that social forces outside the scientific enterprise influence the science teacher's attitude toward science and science teaching, as do the standard science courses he is required to take in his training program. We know very little about these influences and their subsequent effects and yet it seems reasonable to suggest that such data are essential to the rational planning of training programs for science teachers.

The modern science teacher needs much more knowledge than his predecessor, but he must have more than knowledge of science content. Knowing a great deal *about* science is no guarantee that he will know *what science is about*. Prevailing concepts of the competent science teacher need to be reexamined and tested against the realities of on-going teaching situations. To do this intelligently and systematically, studies and investigations such as are implied here will be surely needed.

Horizons of Knowledge of the Cell*

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I would like to trace some of our present day concepts of the structure and function of parts of the cell and what we may hope to see emerge in this field of research in the near future. Most of these observations will concern animal cells, partly because they are larger and have a more complex morphology than bacterial cells, and also because they are better studied than most other forms.

Figure 1 shows some of the structural components found in most cell types which have been studied. These structures were hinted at by light microscopy toward the end of the 19th century but most of these, the mitochondria, the Golgi apparatus, the centromere were at the very limit of visibility. Most cytologists distrusted these observations and the view came about that the cytoplasm, in particular, was

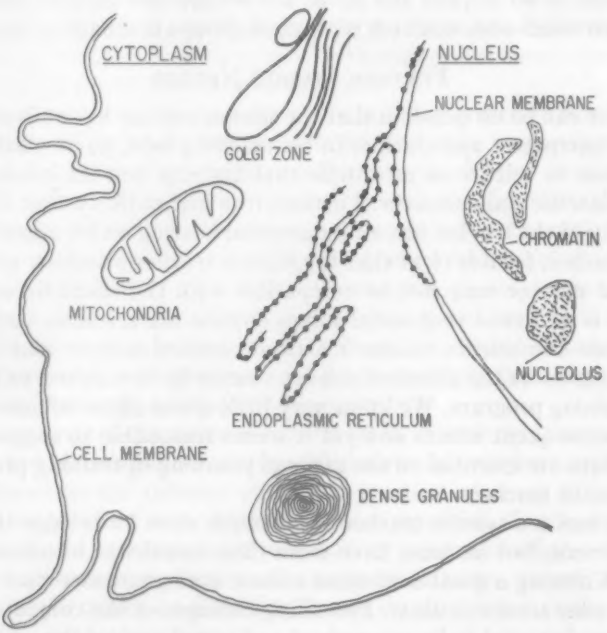

FIG. 1. Diagrammatic representation of intracellular components found in most animal cells.

* Adapted from a lecture given before the 60th Annual Convention of the Central Association of Science and Mathematics Teachers, November, 1960.

a colloidal, but structureless area. The cell could be thought of as a bag of enzymes, and the task of the biochemist clearly was to isolate each enzyme and thus obtain a complete answer to the mechanism of the reactions involved in utilizing food stuffs and building new cellular material.

After the war, a new tool emerged for ultramicroscopy; the electron microscope. In the last 10 years, and particularly in the last 5 years, extensive studies have been made of very thin sections of cells fixed and stained by various means (Novikoff, 1956). Favorite methods have been treatment of the tissue with osmium salts and shadowing with gold to make parts of the cell more visible by rendering them opaque to the electron beam. What has emerged is that the cytoplasm is full of highly organized structures (Figure 2) in the form of membranous materials which provide vast surfaces on which reactions

FIG. 2. Electron micrograph of a thin section of a pancreatic cell of the guinea pig. Notice the regular array of membranes of the endoplasmic reticulum and the sectioned mitochondria showing inner membranes. The nuclear membrane is clearly visible. Reprinted by permission of G. E. Palade, the Rockefeller Institute, and J. Biochem. Biophys. Cytolol. (Vol. 2, supplement p. 85, 1956).

FIG. 3. The separation of intracellular components by centrifugation.

may take place (see Oberling, 1959). Hand in hand with these studies on the morphology of cellular structures has gone the work of the biochemist who has been able to isolate these same structures, or pieces of them, by the use of the ultracentrifuge. Figure 3 shows the principle of such a separation as worked out by Claud (1943) and later used by Hogeboom, Schneider and many others. The cells are broken by grinding, or some other suitable means, in a sucrose solution and then centrifuged over a density gradient of sucrose or at different centrifugal speeds. Each group of cellular organelles seeks its own density in the tube and at the end of the centrifugation period can be isolated for study in more or less pure form.

The first unit of importance and the best studied is the mitochondrion, which is found in all cells which have a citric acid cycle for the oxidation of foodstuffs. It is the energy-producing factory of the cell and synthesizes high energy phosphate compounds, in particular, adenosine triphosphate (ATP) for use in the synthetic reactions of the cell. Figure 4 shows a model of the structure of a mitochondrion. Notice the inner membranous partitions or cristae which are continuous with the double outer membrane shown here and in Figures 2 and 5. Oxidation of pyruvic acid to CO_2 and water involves a number of distinct and specific enzymic proteins (Lehninger, 1960). These enzymes are now believed to be located on the inner partitions of the mitochondria and arranged in specific order and spacing for proper interaction. Systems for the capture of the energy released from these oxidations (in the form of transferred electrons) are also located here in what appear to be well defined bundles held together by lipid containing proteins (Green, 1959).

Mitochondria do not all have the same shape. Those from some cells are rounded and in others the cristae appear to form tubules rather than partitions (e.g., the adrenal gland). A number of interesting changes occur in the mitochondria in various pathological conditions. For instance, starved animals show mitochondria with cloudy swelling (see Rouiller, 1960); in this condition the mitochon-

dria take on water and the membranes inside the structures finally disappear. Mitochondria from cancer cells often appear different from those of normal cells and may be present in fewer numbers. An interesting case of association between lipid granules and the mitochondria has been shown by Palade (1959) in the pancreas of fasted guinea pigs. Mitochondria appeared in close contact with the lipid

FIG. 4. Proposed model of a mitochondrion showing inner membranes.[1]

[1] See footnote, p. 213.

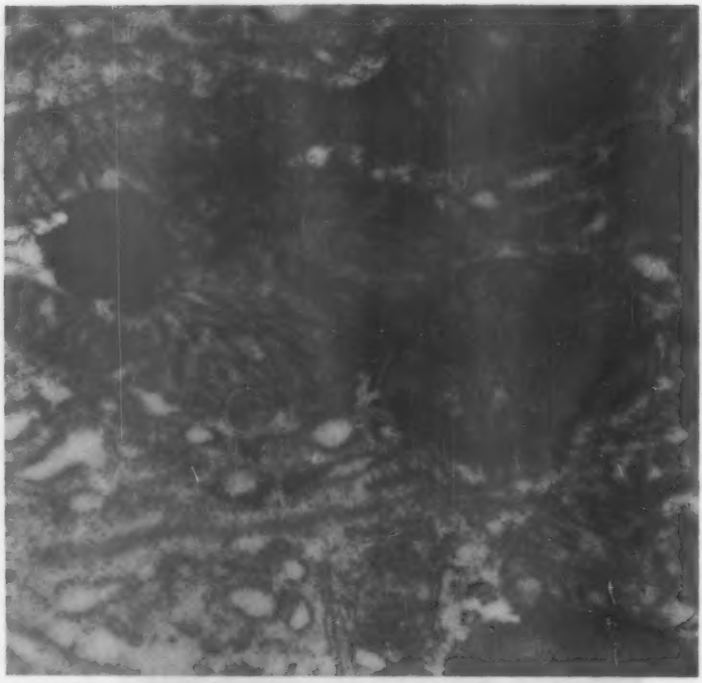

FIG. 5. Electron micrograph of a thin section of a pancreatic cell of the guinea pig showing the inner structure of the mitochondria. (Courtesy of Dr. G. E. Palade, The Rockefeller Institute.)

and in some cases were wrapped around the lipid inclusion. During the fast, fat is mobilized from body stores, moves through the blood stream, enters the cells and becomes associated with the mitochondria which utilize the fat in this lipid droplet for energy in the absence of the usual carbohydrate foods.

Very little is known about how new mitochondria are formed during cell growth but numerous smaller bodies are seen in the cell which may be developing forms of additional mitochondria.

Other smaller, round bodies are also observed in certain cells and have been given the name lysozomes by DeDuve (1959) who has shown that these granules are found in the liver and contain a number of enzymes useful in breaking down nucleic acids and proteins. These particles really do appear to be bundles of enzymes waiting and ready when they are needed. They are isolated from the rest of the cell by their own membrane which may also protect the mother cell from their action. It may be that these activities are used to dis-

FIG. 6. A proposed model of the endoplasmic reticulum showing possible interconnections between layers.[1]

[1] Reprinted from the Scope monograph "The Cell," The Upjohn Company. This 48-page monograph on cytology will be sent to science instructors who request it on their school letterhead from The Upjohn Company, Department 914, Kalamazoo, Michigan.

solve particles of food brought into the cell or that they are expelled from the cell for use as are similar granules of the pancreas known as the zymogen granules.

Of major importance to the cell, and now the subject of intense research, are the membranous structures in the cytoplasm known as the endoplasmic reticulum or ergastoplasm (see Palade, 1956). These appear to consist of canals, vesicles or membranes in the cell and were shown by Palade to contain granules very rich in ribonucleic acid (RNA). Figure 6 shows a model of this system depicting possible interconnections between layers. Figure 7 shows a high magnification of a thin section through these structures. The form of these membranes is very characteristic of the type of cell in which they are found. The ribonucleoprotein granules now are thought to be the chief site of the synthesis of new protein in the cell. When cells are homogenized and centrifuged the membranous structure of the endo-

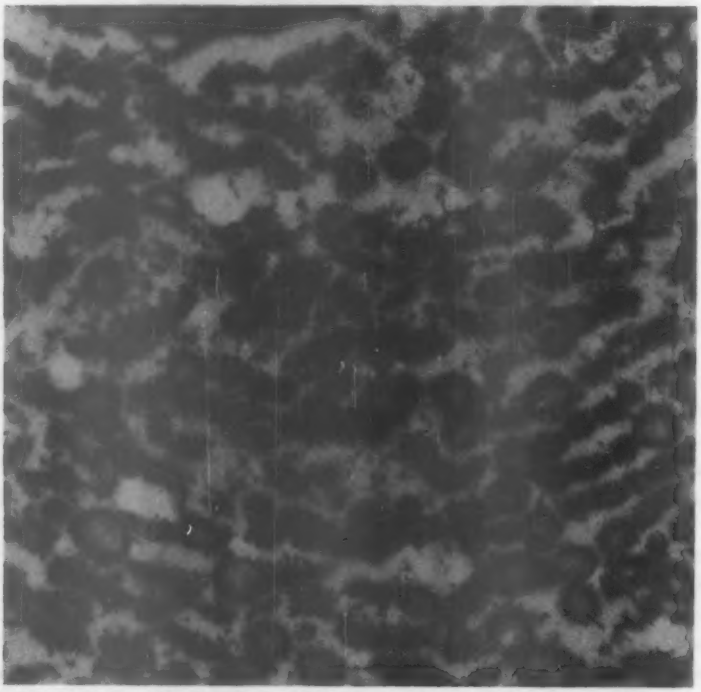

FIG. 7. Electron micrograph of a thin section of a pancreatic cell of the rat showing the ribonucleoprotein particles of the endoplasmic reticulum (courtesy of Dr. G. E. Palade).

plasmic reticulum is not retained and instead small particles with pieces of attached membranes are isolated and have been given the name microsomes. The microsomes have been shown to incorporate radioactive amino acids into proteins, provided these amino acids were first activated by combining with a special molecule of soluble RNA with the help of the ATP made in the mitochondria. This is shown diagrammatically in Figure 8. When all of the proper units are available, the complete protein may be formed on a ribonucleoprotein (RNP) template located in the microsome (see Cohen and Gros, 1960).

The origin of the endoplasmic reticulum itself is an interesting

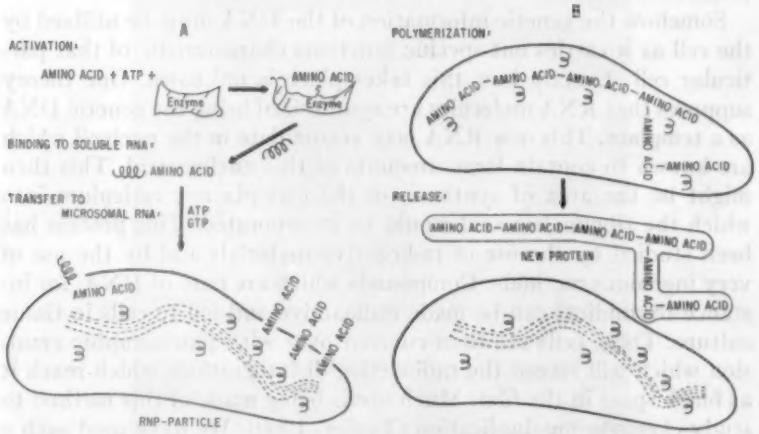

FIG. 8. Schematic representation of the steps involved in synthesis of protein on a microsomal template. The spirals represent RNA.

problem as is the origin of both the particulate and the soluble RNA of the cytoplasm. Much recent research points to the nucleus of the cell as the site of origin, and indeed certain studies with radioactive isotopes, as well as the electron micrographs, indicate a transfer of RNA from the nucleus to the cytoplasm. Some pictures seem to show filaments protruding from pores in the nuclear membrane out into the cytoplasm and some nuclear membranes have a great many pores in their surface.

It has been known for some time that the genetic characters of the cell reside in genes and chromosomes located within the cell nucleus, and it has recently been proved that these genetic characters are coded in the deoxyribonucleic acids (DNA). As may be noticed in some of the preceding figures, the components of the nucleus are not

brought out well by the electron microscope. At the time of cell division the nuclear membrane disappears and the chromosomes condense until they can be seen by the light microscope with proper staining. Each duplicated chromosome splits into two daughter chromosomes, with a complete genetic complement going to each new cell. The exact biochemical mechanism for the duplication of deoxyribonucleic acid as well as the other components of the chromosome is one of the most fascinating studies for the biochemist, since at this level we are very close to studying the process of life itself. As you may recall, Drs. Kornberg and Ochoa last year shared the Nobel Prize in Medicine for their outstanding work on the biosynthesis of the nucleic acids in bacteria.

Somehow the genetic information of the DNA must be utilized by the cell as it carries out specific functions characteristic of that particular cell. Exactly how this takes place is unknown. One theory supposes that RNA molecules are synthesized using the genetic DNA as a template. This new RNA may accumulate in the nucleoli which are known to contain large amounts of this nucleic acid. This then might be the area of synthesis of the endoplasmic reticulum into which the ribonucleic acid would be incorporated. This process has been studied by the use of radioactive materials and by the use of very ingenious methods. Compounds which are part of DNA, for instance thymidine, can be made radioactive and fed to cells in tissue culture. These cells are then covered over with photographic emulsion which will record the radioactive disintegrations which reach it as black spots in the film. Much use is being made of this method to study chromosome duplication (Taylor, 1960). We have used such a system to study the multiplication of vaccinia virus in animal cells grown in tissue culture (Magee, 1960). For this study we have used a strain of human cells (known as HeLa cells) which have been grown in continuous culture in test tubes and bottles in the laboratory since 1951 when they were isolated from a human cervical cancer by Gey (1952). Vaccinia virus is the vaccine virus used to immunize against smallpox, and is the causative agent for cowpox in animals. It is a large virus containing DNA. The virus matures in the cytoplasm and thus DNA appears there. This never occurs in the non-infected cell where DNA is restricted to the nucleus. Figure 9 shows this sequence clearly. The radioactivity from thymidine was incorporated into DNA of the nucleus in the control cells, but occurred in bunches or inclusions in the cytoplasm if added after the cells were infected with vaccinia virus. Later the radioactivity appeared throughout the cell as the virus matured and left the inclusion area. Lately we have observed peculiar inclusion forms in the nucleus very soon after infec-

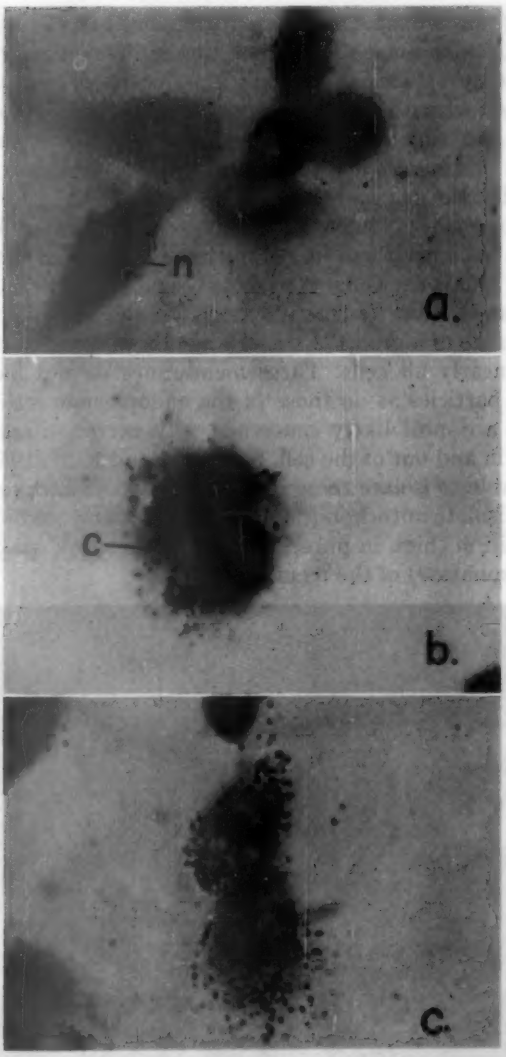

FIG. 9. The localization of thymidine-H^3 in the DNA of HeLa cells infected with vaccinia virus.

a. Control cells. Note localization of silver grains over the nucleus (n) indicating the intracellular localization of radioactive DNA.

b. The cells were given thymidine-H^3 soon after being infected with vaccinia virus. The radioactivity is now localized over new synthetic sites in the cytoplasm (c).

c. Similar cells as in (b) but observed later. The radioactivity spreads all through the cytoplasm as the virus matures.

tion so that now we must speculate as to what role the nucleus itself plays in the infection and whether the cytoplasmic viral DNA is made in the cytoplasm or whether it is localized there after being made in the nucleus. Our ultimate goal in this study is to try to discover how and why the virus is able to "take over" the cellular metabolism and divert it into producing more virus at the expense of and, finally, the death of the cell.

There is one other cytoplasmic structure which has been known for a long time because it can be readily seen by special staining with silver salts. This is the Golgi apparatus (Figure 10). We have no more than hints as to what its true function is in the cell. The Golgi zone usually consists of a group of smooth membranes and vesicles and is present in nearly all cells. These membranes do not have ribonucleoprotein particles as do those of the endoplasmic reticulum. The membranes are most likely concerned with excretion and transport of particles in and out of the cell. Schneider and Kuff (1954) recently have been able to isolate these membranes by much the same methods used to isolate mitochondria or microsomes and are now studying the composition (high in phospholipid) and enzymic make-up (high in acid phosphatase) of the membranes.

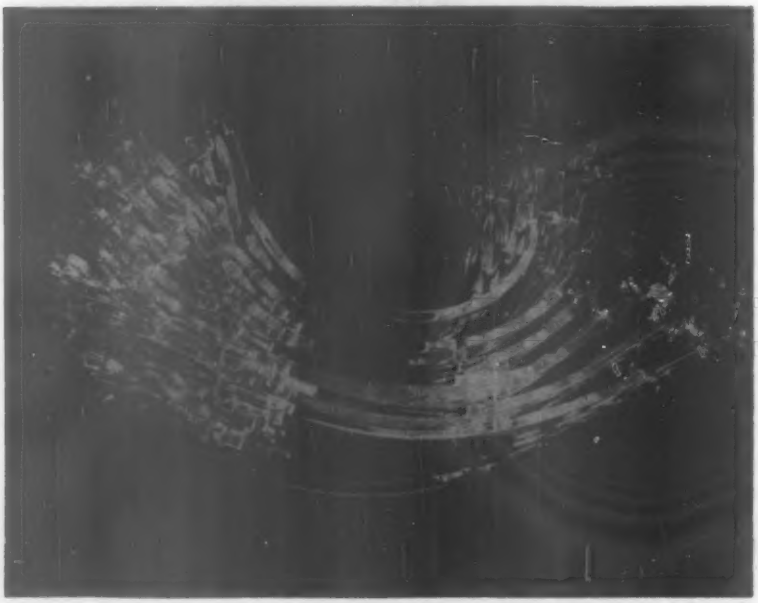

FIG. 10. A model representing the Golgi membranes.[1]

See footnote, p. 213.

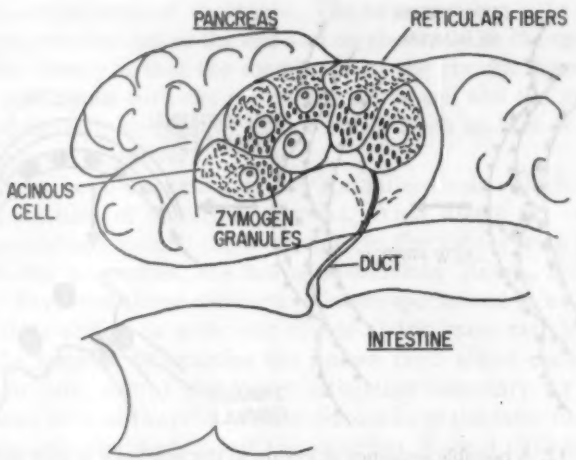

FIG. 11. The function of the pancreas in digestion. After a meal the zymogen granules are discharged into ducts leading to the small intestine. These granules contain hydrolytic enzymes which become activated and are used to digest the food in the small intestine.

I would like now to attempt to integrate much that I have been talking about by taking a concrete example from the recent literature of experiments conducted by Siekevitz and Palade (1960) which were concerned with the synthesis of compounds by the pancreas.

Figure 11 depicts the function of the pancreas in digestion. Enzymes necessary for the breakdown of foodstuffs are synthesized in the pancreas and soon after a meal are discharged into the small intestine through special ducts. Siekevitz and Palade have studied this process in detail and have selected this system to study the interrelationship of structure and activity on an ultra-micro scale. During a fast, the guinea pig builds up large numbers of zymogen granules containing these digestive enzymes. Soon after the animal is fed, these granules are discharged and a new cycle of enzyme synthesis begins. These workers chose this point to inject the animals with a radioactive amino acid. Within minutes this amino acid was being used to make new protein. Figure 12 illustrates the postulated series of steps which take place. The new protein is synthesized on the ribonucleoprotein particles of the cytoplasmic reticulum as diagrammed in Figure 8. The protein then detaches from the particle (release) and collects in the spaces between the membranes and condenses there in the form of dense, intercisternal particles. To do this it may even move across the membrane itself, and this, in fact,

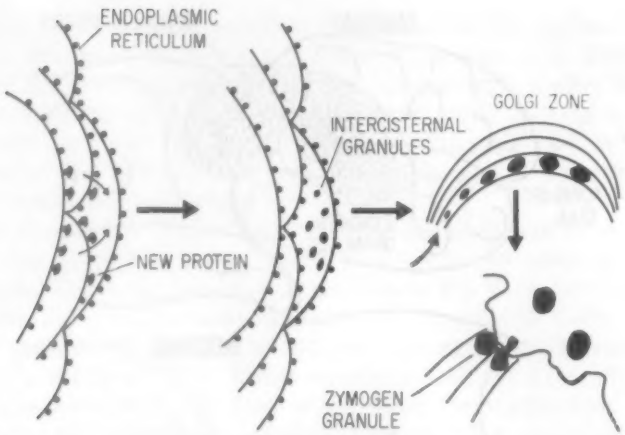

FIG. 12. A possible sequence of events in the synthesis of new protein enzymes by the exocrine cells of the pancreas.

may be a necessary part of the mechanism to condense these proteins into particles. These steps were proved in a very elegant way. The subcellular particles were isolated by centrifugation. You will recall that under these conditions the membranes of the endoplasmic reticulum break up into pieces. These were further separated into the RNP particles themselves and the membranous structures that hold them. Both fractions were isolated and purified. The RNP-particles were further broken down into two fractions. Mitochondria were isolated as was the final supernatant fraction. Then a pure enzyme protein was isolated from each and every one of these fractions—one of the enzymes which finally appears in the zymogen granule and is excreted into the intestine (chymotrypsinogen). Siekevitz and Palade found that within one minute after injection of a radioactive amino acid the very highest radioactivity incorporated into chymotrypsinogen appeared not in the intercisternal particles or the zymogen granules but in the RNP-particles of the reticulum. In other words, they caught these proteins as they were synthesized on their templates. Fifteen minutes after injection the intercisternal granules contained the most radioactive chymotrypsinogen, and by 45 minutes the chymotrypsinogen of, zymogen granules had the most radioactivity.

Part of the theory as to how this intracellular process takes place involves the participation of the Golgi membranes. In some way, the newly-formed enzyme particles must move through the channels of the endoplasmic reticulum and finally collect in the membranes of the Golgi zone. Then the particles fuse and become larger and finally

acquire a membrane of their own. The next problem is to get these zymogen granules out of the cell and on their way to the small intestine. One theory is that the membrane of the granule fuses and becomes continuous with the membrane of the cell and the material is expelled through an opening thus formed. Such an idea is very difficult to prove, however.

We have been discussing rather specialized cells which turn out large quantities of digestive enzymes. What about the cells from other specialized tissues: the liver, muscle, the kidney with its amazing filtering properties, the hormone-secreting glands, and all the others? Even the tissue-cultured cells are specialized in at least one sense; their ability to grow and divide at the same rate forever. It would be possible to examine the known facts about each of these tissues in turn, except this is not altogether necessary for our purpose, since most of the cells of these tissues have the same functioning elements only modified to suit the situation. Recent data even seem to indicate that the blood capillaries transport materials from the blood to the tissue across the capillary cell by means of small vesicles by a process not unlike the discharge of a zymogen granule by the pancreatic cells.

What can we expect in the future? I have tried to imply that the newest developments in the knowledge of the cell are really concerned with the amazing morphological complexity that is becoming more apparent every day. The cell is terrifically organized even in areas which a few years ago appeared to contain only translucent gels. Much immediate effort certainly must go into delving further into how the cell is organized on a molecular level. How are enzymes arranged in the interior of the mitochondria and how are they reproduced in this order? The various steps in electron transport in the mitochondria are being investigated very actively since the whole question of how energy is transferred and stored is involved. Dr. David Green and his coworkers at the University of Wisconsin are attempting to take the system apart in the mitochondria and study it step by step. It is already apparent that the enzymes are embedded in a lipid-protein material so that the electron transfer takes place in a very special environment.

The time also has come when we can begin to put the cell back together reaction by reaction. This study of a new "cellular physiology" on a biochemical level will continue for many years to come. The cell is ever changing in its composition and its activities according to what phase of its growth cycle it is in. The delicate control and counter balance mechanisms that must be brought into play are only just beginning to be investigated. Certainly our medical problems will be solved with increasing frequency as we learn more about the funda-

mentals of cellular knowledge. What could be more exciting than participating in the research and teaching in this area in the coming years?

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TB CAN BE ELIMINATED THROUGH CHEMOTHERAPY

Tuberculosis can be eliminated in the United States through drug treatment.

Dr. Edward T. Blomquist, chief of the tuberculosis branch, division of special health services, U. S. Public Health Service, today called for coordination between public health agencies and communities to stamp out TB.

Eradication of tuberculosis means killing the tubercle bacilli in persons now suffering from the active disease and in those who previously had TB and were inadequately treated. The proper dosage of appropriate drugs, such as isoniazid, over a period of time will make it impossible to communicate the disease to others and will lessen the possibility of recurrence in the patient.

BY-LAWS

Central Association of Science and Mathematics Teachers

As of November 26, 1960

ARTICLE I. MEMBERS

SECTION I. QUALIFICATIONS: Any teacher or other person interested in any aspect of the teaching of science or mathematics shall be eligible for membership in this Association.

SECTION II. ELECTION: A qualified person becomes a member upon submitting a completed application blank and payment of dues.

SECTION III. TERMINATION OF MEMBERSHIP: The membership of any member of the Association shall be automatically terminated for any delinquency of dues, or other charges owing to the Association. During the first six months of such delinquency the person may upon request and payment of back dues be restored to membership without losing continuity of membership. Any member of the Association may be expelled for any reason deemed sufficient by the Board of Directors by a two-thirds affirmative vote of all those present at any meeting of the Board of Directors, or by a two-thirds affirmative vote of all the members present at any meeting of the Association. But no vote of expulsion may be taken unless written notice shall have been given not less than thirty days prior to the date for said meeting to the member proposed to be expelled, which said notice shall advise said member of the time and place of said meeting. and the reasons for which expulsion is proposed. Like notice shall be given to all other members of the Association. It shall be the privilege of the member proposed to be expelled to appear and be heard by the members of the meeting at which a vote is to be taken on the question of expulsion.

SECTION IV. DUES: The annual dues of each member of the Association shall be set by the Board of Directors and will be payable in advance. The annual dues shall entitle the member to receipt of the *Journal*.

SECTION V. VOTING: Each member of the Association shall be entitled to one vote.

SECTION VI. HONORARY MEMBERS: Proposals for honorary members of the Association may be presented by any member of the Association to the Board of Directors, the name of the proposed honorary member shall then be submitted to the members of the Association at any meeting and, upon the affirmative vote of two-thirds of the members present at any such meeting shall be elected to honorary membership in the Association.

Honorary members shall be entitled to all privileges of regular members of the Association, but shall not be required to pay any dues to the Association.

ARTICLE II. MEETINGS

SECTION I. TIME OF MEETING: (*a*) *ANNUAL MEETINGS:* The annual business meeting shall be held on the second day of the annual convention as set by the Board of Directors.
(*b*) *SPECIAL MEETINGS:* Special meetings shall be held at such times as the Board of Directors in its descretion may determine.

SECTION II. PLACE OF MEETINGS: The annual and special meetings shall be held at Chicago, Illinois, or such other place as may be fixed from time to time by the Board of Directors.

SECTION III. QUORUM: Twenty-five members present at any regular meeting shall constitute a quorum.

SECTION IV. ORDER OF BUSINESS: The order of business shall be determined as follows: (a) Roll call. (b) Reading of minutes. (c) Reports. (d) Communications. (e) Unfinished business. (f) New business.

SECTION V. RULES: All questions of procedure shall be determined by "Robert's Rules of Order Revised."

SECTION VI. MAJORITY VOTE: A majority vote of all votes cast shall bind the corporation unless herein, or by the laws of Illinois, otherwise provided.

SECTION VII. NOTICE OF MEETINGS: No notice shall be required for meetings whose time of meeting is fixed in those By-Laws. Written notice of the time and place of all special meetings shall be sent to each member of the Association, said notice to be deposited in the United States mail not later than ten days before the date of special meeting. Each member shall furnish the Secretary with the address to which notice of the meetings shall be sent.

ARTICLE III. OFFICERS

SECTION I. OFFICERS: The officers of this Association shall be a President, a Vice-President, a Secretary and Historian, a Treasurer and Business Manager, an Editor of the *Journal*. One or more Assistant Secretaries, Assistant Editors, and Assistant Treasurers may be appointed by the Board of Directors.

SECTION II. QUALIFICATIONS: Nominees for the Offices of President and Vice-President must have been officers and/or members of the Board of Directors within the past five years.

SECTION III. ELECTION, TENURE OF OFFICE, COMPENSATION:
(a) The President and Vice-President shall be elected by the members of the Association through a majority of the votes cast by the members of the Association and shall serve for a term of one year or until their successors are elected. The Treasurer and Business Manager, Editor of the *Journal*, Secretary and Historian shall be appointed for a term of three years by the Board of Directors at a meeting to be held following the annual meeting of the Association, or at the Spring meeting of the Board of Directors. The Secretary and Historian shall take office immediately following appointment. The Treasurer and Business Manager, and Editor of the *Journal* shall take office at the beginning of the fiscal year following their appointment. They may be reappointed. The compensation of the officers, if any, shall be fixed by the Board of Directors.
(b) The election of officers of the Association shall be by mail ballot to be held each year during the four weeks closing at 12 midnight of the date one week prior to the annual meeting. Official ballots, accompanied by professional biographies of all nominees and pictures of the nominee for President and Vice-President shall be mailed to the members at least five weeks prior to the date set for the annual meeting. Ballots, when properly marked, shall be returned to the Secretary of the Association to be held under seal until the time for the official count. In the event of close votes the Board of Directors may exercise the privilege of calling for a recount, and, in the event of a tie vote, it shall assume the responsibility of determining the procedure for selection of the candidate to be declared elected.

SECTION IV. POWERS AND DUTIES OF OFFICERS:
(a) *PRESIDENT:* The President shall preside at all general meetings of the Association and shall perform the usual duties of his office. He shall be Chairman of the Board of Directors and Chairman of the Executive Committee, and shall perform the usual duties of those offices.
(b) *VICE-PRESIDENT:* He shall act for the President in the latter's absence. He shall serve as a member of the Executive Committee and shall act as Chairman of the Program Committee.
SECRETARY AND HISTORIAN: The Secretary and Historian shall keep all records and minutes of all meetings; shall prepare and submit a complete report

of the Annual meeting to the Editor of the *Journal* by December 31st following the meeting: and shall be charged with the responsibility of collecting and preserving the historical documents of the Association.
(d) *TREASURER AND BUSINESS MANAGER:* The Treasurer and Business Manager shall collect all dues and hold all moneys and keep a record of all receipts and disbursements. He shall give a report at the annual meeting of the Association. He shall pay out funds on the order of the Board of Directors and the Executive Committee.
(e) *EDITOR OF THE JOURNAL:* The Editor of the *Journal* shall be responsible for the *Journal,* in all phases except business management.
(f) *FISCAL YEAR:* The fiscal year shall be from July first to June thirtieth.
SECTION V. NOMINATIONS: Nominations for officers shall be made by the Nominating Committee appointed by the Executive Committee.

ARTICLE IV. BOARD OF DIRECTORS

SECTION I. QUALIFICATIONS: All directors shall be members of the Association.

SECTION II. NUMBER: There shall be fifteen (15) members of the Board of Directors. The president, Vice-President, the President of the preceding year, shall be members of the Board of Directors. The remaining members of the Board of Directors shall be divided into three groups of four (4) directors each. Four directors shall be elected annually to succeed those of the group whose terms are about to expire.

SECTION III. NOMINATIONS: Nominations for directors shall be made by the Nominating Committee appointed by the Executive Committee.

SECTION IV. ELECTION, TENURE OF OFFICE AND COMPENSATION: Directors shall be elected by the members of the Association by a plurality of the votes cast by the members of the Association. The four nominees receiving the largest number of votes cast in the annual election as described in Section III (b) of Article III shall be declared elected to the Board of Directors. In case of a tie the decision shall be made by lot under the supervision of the Chairman of the Nominating Committee and the Secretary of the Association. They shall assume the duties of their office immediately preceding the adjournment of the annual meeting and shall serve for a period of three years or until their successors are elected. They shall serve without compensation, except that they may be allowed a reasonable compensation for travelling, and necessary expenses incurred by them in the discharge of their official duties. Vacancies in the Board of Directors or list of officers shall be filled by the Board of Directors. A director so chosen shall serve for the remainder of the unexpired term, when nomination and election shall take place as provided above.

SECTION V. TIME AND PLACE OF MEETINGS: Meetings of the Board of Directors shall be held immediately preceding the annual meeting of the Association and at such other times and places as may be determined by the President or the Executive Committee of the Association.

SECTION VI. QUORUM: Five members of the Board of Directors shall constitute a quorum.

SECTION VII. ORDER OF BUSINESS AND RULES: The order of business and rules shall be the same as those governing the general meetings of the Association.

SECTION VIII. POWERS AND DUTIES: The Board of Directors shall (1), have general supervision of the activities of the Association; (2), authorize the expenditure of funds; (3), fix the salary and bonds of the officers; (4), fill vacancies.

ARTICLE V. EXECUTIVE COMMITTEE AMD OTHER COMMITTEES

SECTION I. EXECUTIVE COMMITTEE:
(a) *MEMBERS:* Members of the Executive Committee shall consist of the President, the Vice-President, and the immediate past president, and shall serve for one year or until their successors have been elected.
(b) *MEETINGS:* Meetings of the Executive Committee shall be held from time to time and at such place as the Committee may designate.
(c) *QUORUM:* Two members shall constitute a quorum.
(d) *POWERS AND DUTIES:* The Executive Committee shall have direct charge of the work of the Association subject to the supervision of the Board of Directors.

SECTION II. NOMINATING COMMITTEE
(a) Promptly following the Annual meeting of the Association, the Executive Committee shall appoint a committee of five (5) to be known as the NOMINATING COMMITTEE;
(b) The membership of this Committee shall be so selected as to present a balanced representation of the Association according to sectional, geographical, and level-of-teaching areas distribution;
(c) The Chairman of the Committee shall be designated from this group by the Executive Committee;
(d) The term of service on the Committee shall be one year;
(e) The Committee shall nominate two candidates for the office of President and two candidates for the office of Vice-President, and twice as many candidates as there are positions to be filled on the Board of Directors.
(f) All nominees must be members of the Association, currently in good standing and properly qualified according to the By-Laws;
(g) The Chairman shall provide for mailing the membership necessary pictures and professional biographies of the nominees;
(h) The Chairman of the Committee and the Secretary of the Association shall have the joint responsibility of making the official count of all votes cast in the Annual election. They shall provide the President of the Association prior to the time of the annual meeting of the Board of Directors, with a report, over their signatures of the results of the official count.

SECTION III. JOURNAL COMMITTEE:
(a) *MEMBERS:* The *Journal* Committee shall consist of five (5) members. Nominations to membership on the Journal Committee shall be made by the Executive Committee of the Association.
(b) *POWERS AND DUTIES OF THE JOURNAL COMMITTEE:* The *Journal* Committee shall have general direction of the management and policies of the Journal of the Association, subject at all times to the approval and supervision of the Executive Committee and the Board of Directors of the Association.
(c) *TENURE OF OFFICE:* Membership in the *Journal* Committee shall be at the pleasure of the Executive Committee and the Board of Directors of the Association.

SECTION IV. PROFESSIONAL SECTIONS AND GROUPS: The Association may be organized into sections and groups. The organization and activities of the sections or groups shall be determined from time to time by the Board of Directors. Unless otherwise provided by the Board of Directors each section or group shall elect its own Chairman, Vice-Chairman, and Secretary.

SECTION V. PROGRAM COMMITTEE: The Program Committee shall consist of the chairmen of all sections, the Vice-President, and other such members as the President may appoint. The Vice-President shall act as chairman of the committee. The Program Committee shall prepare and have charge of the program of the annual meeting of the Association.

SECTION VI. MEMBERSHIP COMMITTEE: Membership Committee and others may be appointed from time to time by the President of the Association.

SECTION VII. THE POLICY AND RESOLUTIONS COMMITTEE: The Policy and Resolutions Committee shall consist of six (6) members. Each member shall serve three years. Two members shall be chosen annually by the President to replace the two whose terms are about to expire. One of those chosen annually must be from the Board of Directors. The President will annually designate the chairman of this committee. The Chairman so selected shall have been a member of the committee for at least one year.

ARTICLE VI AMENDMENTS

The By-Laws may be amended by two-thirds (2/3) vote of the regular members present at any regular meeting of the Association, or at any special meeting of the Association called for the purpose of voting on such amendment, provided the proposed amendment has been published in two successive issues of School Science and Mathematics.

Central Association of Science and Mathematics Teachers

REPORT OF THE SIXTIETH CONVENTION

NOVEMBER 24–26, 1960, STATLER HILTON HOTEL, DETROIT, MICHIGAN

I. BOARD OF DIRECTORS MEETING

THURSDAY, NOVEMBER 24, 1960, 4:00 P.M., PARLOR C

Roll Call

Officers: Otto, Conrey, Shetler, Kennedy
Directors: Ambrosia, Grubbs, Hach, Hill, Sistler, Woline, Wood
Policy and Resolution Committee Chairman: Read
General Coordinator for the Convention: Hovespian
Minutes of 1960 Spring Board Meeting: Read and approved.
Report of Nominating Committee: The successful candidates elected in the recent election are:
President: Cecil B. Read V. Pres.: Alice M. Hatch
Directors: Carl W. Clader, M. Wiles Keller, T. Reginald Porter, Joseph J. Urbancek

Hach moved that a request for suggestions for nominations be included in the *Journal*. Motion seconded and carried.

The report of the Nominating Committee was received.

Report of Place of Meeting Committee: Woline reported that the 1961 Convention would be held in Chicago. The role of this committee had not been fully clarified in the reorganization of the Association offices at the 1960 Spring Board Meeting. Hach moved that the Place of Meeting Committee be continued as a matter of Board policy and that the Secretary be an Ex-Officio member. This Committee is to encourage and receive invitations and report these to the Board. Motion seconded and carried.

Report of Program Committee: Otto thanked Conrey for his work during the past year. Grubbs moved that the question of convention expense budgeting be referred to the Policy and Resolutions Committee for a report at the Spring Board Meeting. Motion seconded and carried. Program Committee report received with thanks.

Hach moved that the Secretary-Historian and Treasurer-Business Manager continue to study the reorganization of their offices and report to the Board before the Spring Board Meeting. Motion seconded and carried.

Report of General Coordinator of the Convention: Hovespian reported briefly on the work of his committee. He said that having some available expense allowance would be helpful. He suggested that we consider increasing our registration fee.

Sistler suggested that a continuing file on each local committee be kept. The report was received with thanks.

Report of Treasurer and Business Manager: Soliday's report had been mailed to the Directors before the Convention. This report showed that the fiscal year ending, June 30, 1960 was profitable financially. Details of the transfer of office responsibilities, records, and equipment from Oak Park to Bluffton and Terre Huate were included.

Shetler also reported to the Board. He expressed his appreciation for the help of the Solidays in transferring the office. Shetler commented that we have a problem of making best use of our surplus funds. These reports were received with thanks.

Report of Secretary-Historian: This report discussed problems of establishing a new office, activities of the Secretary since June, and some future plans. Report received.

Report of Yearbook Editor: Shetler will retain this work as Treasurer and Business Manager. He reported that 9400 *Yearbooks* had been printed, that we had fifty-one advertisers and exhibitors, and that the *Yearbook* showed a profit of $350. His report was received with thanks.

Report of Membership Committee: Porter's report showed that our membership remained constant despite an increase in dues. He described various activities of this committee. Since the work of this committee is similar to that now assigned to the Secretary, the Board felt that the Secretary should chair the Membership Committee. The report was received.

Grubbs moved that emeritus membership be granted to Enoch Burton. Motion seconded and carried.

Hach moved that the Board approve the action taken by the Soliday Tribute Committee in recognizing the retirement of the Ray Solidays, the Treasurer and Business Manager. Seconded and carried.

Meeting adjoured at 6:55.

II. ANNUAL BUSINESS MEETING

FRIDAY, NOVEMBER 25, 1960, 7:30 P.M., BALLROOM

Meeting called to order by Otto who spike briefly on the Horizons of CASMT.

Minutes of the 1960 Business Meeting were approved as published in the *Journal.*

Wilcox, Chairman of the Nominating Committee, announced election results.

Woline, Chairman of the Place of Meeting Committee, announced that the 1961 convention is to be held in Chicago. He requested invitations for future conventions.

The Policy and Resolutions Committee had considered questions involving By-Laws. They suggested two changes and the Board approved. Both amendments, as published in October and November, 1960, were approved by those Association members present.

Enoch Burton, Fred Schriever, and E. G. Hexter were presented (in absentia) Emeritus Membership Certificates.

Otto thanked Lawrence Conrey, Paul Hovespian, and others who were involved in preparing and conducting the convention. He also expressed his appreciation of the financial assistance of the Metropolitan Science Club and Detroit Teachers of Mathematics Club.

Meeting adjourned.

III. BOARD OF DIRECTORS MEETING

SATURDAY, NOVEMBER 26, 1960, 2:00 P.M., PARLOR C

Roll Call:

Officers: Read, Hach, Shetler, Mallinson, Kennedy

Directors: Ambrosia, Clader, Coarey, Hill, Keller, Laird, Otto, Porter, Urbancek, Vannatta, Woline, Wood.

Read read letters of resignation from Bullington who had been appointed Regional Education Advisor for Science for Southeast Asia by the I.C.A. and from Kennedy whose duties as Secretary have been greatly expanded. Resignations accepted.

Hach moved that Conrey and Laird be appointed to fill these vacancies. Seconded and carried.

Mallinson's report showed that material is available for the next few issues of the *Journal*. A sufficient number of high quality articles is not available for an expanded *Journal*, however. This report included comments on a new feature, departmental editor changes, relationship with the publisher, and a necessary expansion of office facilities. The report was accepted with thanks.

The Policy and Resolutions Committee's report confirmed earlier Board action which restricted student members to full time undergraduate students. The meeting of this committee prior to the Spring Board Meeting was strongly encouraged. Mallison has recieved requests for copies of microfilmed early issues. Board urged that a previously approved contract with the Johnson Co. be initiated. Report received.

Discussion of the convention expense budget lead to a motion by Woline that an advance payment of $50 be made to the Vice-President for convention expense and that this be itemized in the budget. Seconded and carried. Conrey reported that total convention expense would be about $650. In response to a question on a possible increase in registration fees Woline moved that the Policy and Resolutions Committee consider this question and that the Treasurer and Business Manager prepare a budget based on present fees and one on increased fees. Motion seconded and carried.

Read announced the appointment of Porter to the Policy and Resolutions Committee and the appointment of Ambrosia to this committee. Also, the Nominating Committee of Hill (Ch.), Fitch, McCormick, Osborne, and Wilcox. Sistler is chairman of the Place of Meeting Committee and Shorde of the Local Arrangements Committee.

After much discussion Otto asked that the Policy and Resolution Committee re-consider and clarify our relationship to A.A.A.S.

The Board formally thanked President and Vice-President for a fine convention.

Meeting adjourned.

Respectfully submitted,
JOE KENNEDY
Secretary

CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS

AN INVITATION

You are invited to submit a paper on the teaching of mathematics or science for possible use in the Short Papers Session of the 1961 CASMT Convention. This is an opportunity to share an idea on teaching, tell of your own efforts in curriculum revision, or to ask questions of authors and researchers. Your paper should be short (5–10 minutes reading time) and in good form. A balanced program will be compiled from papers submitted before June 1. Send all papers to:

JOE KENNEDY
Indiana State Teachers College
Terre Haute, Indiana

Problem Department

Conducted by Margaret F. Willerding

San Diego State College, San Diego, Calif.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the Department desires to serve her readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, San Diego State College, San Diego, Calif.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Solutions should be in typed form, double spaced.

2. Drawings in India ink should be on a separate page from the solution.

3. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

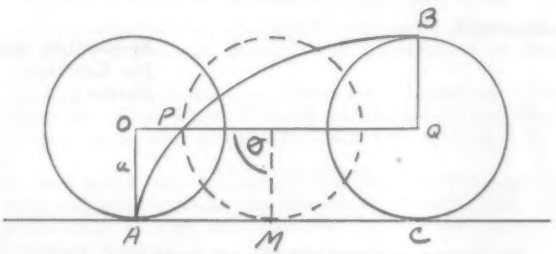
4. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

2739. *T. R. Curry, Oyster Bay, N. Y.*

2749. *Proposed by G. P. Speck, Virginia, Minn.*

If a spoke of a wheel is initially perpendicular to the horizontal, determine the area cut by the spoke as the wheel rolls along the horizontal completing one revolution.



Solution by Fred A. Miller, Elkins, West Va.

Point O follows the line OPQ.
Point A follows the cycloid APB.
Area generated by

$$OA = 2[\text{Area } AOP + \text{Area } PBQ]$$

Point P is reached when

$$\theta = \frac{\pi}{2}$$

Equation of cycloid:

$$x=a(\theta-\sin\theta)$$
$$y=a(1-\cos\theta)$$

$$\text{Area } AOP=\int_0^{\pi/2}[a-a(1-\cos\theta)]\cdot[a(1-\cos\theta)]\cdot d\theta$$
$$=a^2\left[1-\frac{\pi}{4}\right]$$

$$\text{Area } PBQ=\int_{\pi/2}^{\pi}[a(1-\cos\theta)-a]\cdot[a(1-\cos\theta)]\cdot d\theta$$
$$=a^2\left[1+\frac{\pi}{4}\right]$$

$$\text{Area generated}=2\left[a^2\left(1-\frac{\pi}{4}\right)+a^2\left(1+\frac{\pi}{4}\right)\right]$$
$$=4a^2$$

2750. *Proposed by Robert L. Guderjohn, Eugene, Ore.*

How many ways will m like balls go into n different boxes?

Solution by the proposer

The first ball will go into any of n boxes or with any of $m-1$ other balls to be considered as one ball again. The second ball will go into n boxes or with $m-2$ balls, and so on to the last ball. The total number of ways is the product of ways for each ball divided by the permutations of the balls:

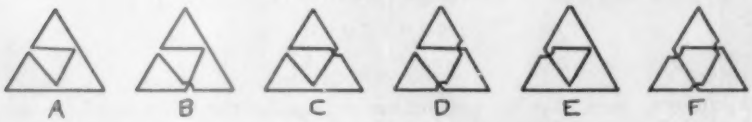
$$\frac{(n+m-1)(n+m-2)\cdots n}{m!}=\frac{(n+m-1)!}{(n-1)!m!}.$$

Solutions were also offered by Bernard T. Pleimann, Gardena, Calif.; and Alan Wayne, Baldwin, N. Y.

2751. *Proposed by C. W. Trigg, Los Angeles City College*

The mid-points of the sides of an equilateral triangle are joined, thus forming an assemblage of nine equal line segments. (a) Starting at a particular vertex, how many continuous paths may be followed in traversing each segment once only while returning to the original vertex? (b) How many essentially different path patterns are involved?

Solution by the proposer



(a) Each of A, B, C, D, E, may be rotated into two other aspects with reference to the top vertex. Also the journey may be started from the top vertex toward either right or left. Hence, there are $2(3\cdot5+1)$ or 32 different continuous paths which may be followed in the journey from a vertex back to the same vertex.

(b) There are 6 essentially different path patterns as shown in the figure. If B and C be considered as the same, since one is the mirror image of the other, the number reduces to 5.

2752. *Proposed by Donald R. Byrkit, West Chicago, Ill.*

The thirteenth of the week is more apt to be Friday than any other day of the week. Prove that this is true or false.

Solution by Alan Wayne, Baldwin, N. Y.

This was proposed as problem E 36 in the *American Mathematical Monthly*, and the solution is given on page 607 of Vol. 40 (1933) as follows.

The calendar repeats in every 400 years, since there are exactly 20,871 weeks in 400 years. In this period, the 13th of the month occurs 4800 times as follows: Sunday, 687; Monday, 685, Tuesday, 685; Wednesday, 687; Thursday, 684; Friday, 688; and Saturday, 684. So in the long run, the 13th is most likely to fall on Friday.

2753. *Proposed by Walter H. Carnahan, Madison, Ind.*

I was riding on a train from Chicago to New York. I called the porter and asked for a table to be placed in my roomette so that I could work on a manuscript. When he set up the table I laid out some mathematics manuscript and began to work. He saw the numbers and sketches but made no remark. However, later he returned, laid a piece of paper on my table, and said, "Suh, can you tell me how come that is so? A man he give me them numbahs." On the paper, was written the expression $342=97$. Now I ask you to explain how come?

Solution by Peter A. Steveson, Bob Jones Academy, Greenville, S. C.

Obviously, for $342=97$, the two numbers have different radices. Thus:

$$342_{(\text{radix } m)}=97_{(\text{radix } n)}$$

$$3m^2+4m+2=9n+7$$

$$n=\frac{3m^2+4m-5}{9}$$

For n to be an integer, m must be of the form $9a+5$, $a\geq 0$. Substituting for m, n takes the form $27a^2+34a+10$. Thus:

$$342_{(\text{radix } m)}=97_{(\text{radix } n)}$$

for $m=9a+5$, $n=27a^2+34a+10$, $a\geq 0$.

Solutions were also offered by Bernard T. Pleimann, Gardena, Calif.; Rose Trahey, Chicago, Ill.; C. W. Trigg, Los Angeles, Calif.; Lowell Van Tassel, San Diego, Calif.; Alan Wayne, Baldwin, N. Y.; and the proposer.

2754. *Proposed by Enoch J. Haga, Vacaville, Calif.*

An accounting student had the multiplication to perform:

$$\begin{array}{r} 219912000 \\ \underline{\qquad\qquad 64} \\ \end{array}.$$

Mystified to learn that the product exactly equaled the multiplicand, he rechecked his work and found that he had made no mistake in his multiplication. What was his error?

Solution by C. W. Trigg, Los Angeles City College

If the student found that $M\times m=P$, he must have made a mistake in the total process of multiplication. Furthermore, he made the mistake of dropping a terminal zero from each partial product, and then failed to indent the second partial product. Thus,

$$
\begin{array}{r}
2\,1\,9\,9\,1\,2\,0\,0\,0 \\
\underline{\qquad\qquad 6\,4} \\
8\,7\,9\,6\,4\,8\,0\,0 \\
1\,3\,1\,9\,4\,7\,2\,0\,0 \\
\underline{2\,1\,9\,9\,1\,2\,0\,0\,0}
\end{array}
$$

Solutions were also offered by Bernard T. Pleimann, Gardena, Calif.; and the proposer.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

Editor's Note: For a time each student contributor will receive a copy of the magazine in which his name appears.
For this issue the Honor Roll appears below.

2749. *Floyd D. Wilder, Bethany Nazarene College, Bethany, Okla.*

2751, 2753. *Richard Lewis Breisch, Royersford, Pa.*

2753. *Robert Nathan Cahn, Menlo-Atherton High School, Atherton, Calif.*

S-6. *Carlos C. Shaw, Rosario, Argentina.*

PROBLEMS FOR SOLUTION

2773. *Proposed by Lowell Van Tassel, San Diego, Calif.*

Slide rules come in various lengths (and even shapes!). It is true that a 6 inch pocket slide rule is only 60% as accurate as a (standard) 10 inch rule? Is a 20 inch desk slide rule 100% more accurate than a 10 inch rule? State the general principles employed in establishing the relative accuracy calculations, and, using the 10 inch rule as standard, evaluate the other length rules, as well as one of arbitrary length k.

2774. *Proposed by Ned Harrell, San Carlos, Calif.*

Find integers x, y and z such that

$$x(2\log 105+\log 1215)+y(3\log 105+\log 875)-z(2\log 105+\log 45)+\log 3=0.$$

2775. *Proposed by C. W. Trigg, Los Angeles City College*

For what values of x is $3x^7-259$ divisible by 547?

2776. *Proposed by Fred L. Bedford, Phoenix, Ariz.*

Given any four points, draw lines through the four points so that the four lines will form a square.

2777. *Proposed by Donald R. Byrkit, West Chicago, Ill.*

What two rational fractions, with denominators less than 100, most closely approximate $\sqrt{61}$ by excess and defect?

2778. *Proposed by Felix John, Philadelphia*

Find two numbers whose sum, whose product and the difference of whose squares are all equal.

Books and Teaching Aids Received*

ASTRONOMY

AN INTRODUCTION TO ASTRONOMY, by Robert H. Baker. Cloth. 14.5×23 cm. 364 pages. 1960. D. Van Nostrand Company, Inc. 120 Alexander Street, Princeton, New Jersey.

TEACHING GUIDE FOR THE EARTH AND SPACE SCIENCE COURSE. Paper. 28×21.5 cm. 105 pages. 1960. National Aviation Education Council, 1025 Connecticut Ave., N.W. Washington 6, D. C. Price $1.00.

BIOLOGY

BIOLOGY—A BASIC SCIENCE, by Elwood D. Heiss, *New Haven State Teachers College, New Haven, Connecticut* and Richard H. Lape, *Amherst Central High School, Snyder, New York*. Cloth. 16.5×24 cm. Pages xi+689. 1961. D. Van Nostrand Company, Inc., 120 Alexander Street, Princeton, New Jersey. Price $5.56.

ECOLOGY OF INLAND WATERS AND ESTUARIES, by George K. Reid, Professor of Biology, Florida Presbyterian College, St. Petersburg, Florida. Cloth. 14×23 cm. Pages xi+375. 1960. Reinhold Publishing Corporation, 430 Park Avenue, New York 22, N. Y. Price $7.80.

WORKBOOK AND EXPERIMENTS FOR BIOLOGY, by Cecelia J. Lauby, *Illinois State Normal University*, James C. Silvan, *New Haven State Teachers College*, Gordon M. A. Mork, *University of Minnesota*. Paper. 19×27.5 cm. 202 pages. 1958. American Book Company, 55 Fifth Avenue, New York 3, New York. Price $2.16.

GENERAL SCIENCE

THE MACMILLAN SCIENCE-LIFE SERIES. By Barnard, Stendler, Spock, and Beeler. Both Cloth. Both 17.5×23.5 cm. Both 422 pages. 1960. The Macmillan Company, 60 Fifth Avenue, New York, New York.

SCIENCE/A WAY TO SOLVE PROBLEMS
SCIENCE/A SEARCH FOR EVIDENCE

MATHEMATICS

ARITHMETIC FOR THE MODERN AGE, by Aaron Bakst. Cloth. 13×21 cm. pages vii+341. 1960. D. Van Nostrand Company, Inc., 120 Alexander Street, Princeton, New Jersey. Price $4.95.

ANALYTIC GEOMETRY AND CALCULUS, by Frank L. Juszli, *State Technical Institute, Hartford, Connecticut*. Cloth. 14×22.5 cm. Pages xii+348. 1961. Prentice-Hall, Inc., Englewood Cliffs, N. J. Price $6.75.

PHYSICS

PHYSICS FOR EVERYBODY, by Germanine and Arthur Beiser. Paper. 191 pages, 9.5×18.5 cm. 1960. E. P. Dutton & Co., Inc., 300 Fourth Ave., New York. N. Y. Price $1.15.

BASICS OF ANALOG COMPUTERS, by Thos. D. Truitt, *Director of Advanced Study Group* and A. E. Rogers, *Senior Consultant, Electronic Associates, Inc.* Cloth. 400 pages. 14×22.5 cm. 1960 John F. Rider Publisher, Inc., 116 West 14th Street, New York, New York. Price $12.50.

* Beginning with this issue, at the suggestion of the Editorial Board, the books and other teaching aids received by the *Journal* will be classified into general categories to which they most logically seem to belong. We hope this new system will be of assistance to our readers.

SCIENCE, MISCELLANEOUS

THE FOUNDATIONS OF SCIENCE, by Sheldon J. Lachman, *Wayne State University*. Cloth. 12×21 cm. 120 pages. 1960. Vantaei Press, Inc., 120 West 31 Street, New York 1, New York. Price $2.95.

THE WONDER OF LIGHT, by Hy Ruchlis. Cloth. 14.5×23.5 cm. 154 pages. 1960. Harper & Brothers, 49 East 33rd Street, New York 16, N. Y. Price $2.95.

ORBIT, by Hy Ruchlis. Cloth. 15×23.5 cm. 147 pages. 1960. Harper & Brothers, 49 East 33rd Street, New York 16, N. Y. Price $2.75.

OUR ATMOSPHERE, by Theo Loebsack. Paper. 9×17.5 cm. 190 pages. 1960. New American Library of World Literature, Inc., 501 Madison Avenue, New York 22, N. Y. Price $.50.

HARPER SCIENCE TODAY SERIES. All cloth. All 11.5×18.5 cm. 1960. Harper & Brothers, 49 East 33rd Street, New York 16, N. Y. All $2.25.

MATTER AND ANTIMATTER, by Maurice Duquesne, *Director of Research in Nuclear Physics at the Radium Institute, Paris*. 127 pages.

THE WIDER UNIVERSE, by Paul Couderc, *Astronome titulaire de L'Observatoire de Paris*. 128 pages.

INTELLIGENCE: ITS EVOLUTION AND FORMS, by Gaston Viaud, *Professor of Psychophysiology and Director of the Laboratory of Animal Psychology Strasbourg*. 127 pages.

THE ANATOMY OF PLANTS, by P. Font Quer. *Formerly, Professor of Botany, and Director of the Botanical Institute, Barcelona*. 128 pages.

EFFECTIVE READING IN SCIENCE, by David L. Shepherd, *Director of The Reading Center, Charlotte Public Schools*, Cloth. 13.5×21.5 cm. 128 pages. 1960. Row, Peterson & Company, Evanston, Illinois.

MISCELLANEOUS

PICTORIAL POSTER MAP. Wisconsin. Paper. 17×22 in. Suitable for framing. Childrens Press, Inc., Jackson Blvd. & Racine Ave., Chicago 7, Illinois.

LIBERAL EDUCATION AND ENGINEERING, by Edwin J. Holstein and Earl J. McGrath. Paper. 14×23 cm. 132 pages. 1960. Bureau of Publications, Teachers College, Columbia University. Price $2.75.

NEW SCIENCE WEEKLY

Wesleyan University (Middletown, Conn.) announces *Science and Math Weekly*, a new weekly science newspaper for senior high school classes in biology, chemistry, physics, and mathematics. *Science and Math Weekly* (for senior high schools) is a companion publication to *Current Science* (for junior high grades), one of the American Education Publications weekly series.

The new weekly answers the demand of many teachers for bridging the gap between the textbooks and recent developments in science and science instruction. Its editorial staff at Wesleyan combines the efforts and experience of college and university teachers with high school teachers.

Science and Math Weekly is edited for high school classes and is also valuable for use in junior college science courses. Scheduled publication is 32 weekly issues during the school year. First issue is dated December 7. The cost per student is 50¢ per semester, $1.00 per school year, in class orders of 10 or more copies. The teacher receives a free desk copy and the Teacher's Editions with class orders. Subscriptions and inquiries filled from *Science and Math Weekly*, Education Center, Columbus 16, Ohio.

Book Reviews

THE TEACHING OF SECONDARY MATHEMATICS, Third Edition, by Charles H. Butler and F. Lynwood Wren. Cloth. 1960. 1960. 17×23.5 cm. ix+624 pages. McGraw-Hill Book Company, 330 West Forty-Second Street, New York 36, New York. $7.50.

The Second Edition of this classic text, written by two experienced and capable educators, was reviewed in SCHOOL SCIENCE AND MATHEMATICS, Volume 53, page 337–8 (by another reviewer). The authors point out in the preface that a new revision is needed to take account of the profound changes which have taken place respecting mathematical education in the secondary schools. In the opinion of this reviewer the authors have done a splendid job in evaluating some of the new developments without going overboard in either an ultraconservative or an ultraliberal opinion. This reviewer would comment especially on the splendid treatment of the historical developments of certain subjects. In particular, he was pleased with the material headed "The Evolving Program of Secondary Mathematics" which occurs on pages 3–41. Another outstanding feature is the large number of bibliographical references. The material on the teaching of the calculus, although aimed specifically at the high school, could be read with profit by many college teachers.

The reviewer was particularly pleased, as has been noted, by the sense of balance maintained by the authors. A single example taken from many is the discussion of drill found on page 172 "Drill must be recognized as an essential means of attaining some of the desired controls, just as a strong emphasis upon concepts and meanings must be regarded as essential for understanding. Both are necessary and neither alone is sufficient. . . . If instruction is to be valuable, however, understanding must go hand in hand with operational facility. With a few possible exceptions children should not be drilled on procedures which they do not first understand." The reviewer was likewise pleased with the implication (page 46) that the underlying philosophies in some of the modern developments are "pretty much the same." This is in spite of the fact that this reviewer was at a recent convention of CASMT emphatically told that this is by no means true.

There are a few places which seemed unusual or with which the reviewer does not completely agree. On page 291 it is odd to find in a book by Butler a quotation cited from this same Butler. On page 367 one wonders whether the cost of gasoline at thirty-four cents a gallon is in reality a straight line or a step function. Perhaps the theoretical cost is a straight line, the actual price paid can only vary in increments of a whole number of cents. In the discussion of exponents on page 409 it is unfortunate that the restriction was not stated that a must not be zero. On page 574, item 2, in the discussion of curves in polar coordinates is an excellent example of a condition which is sufficient but not necessary. This might well have been pointed out.

The minor points which have been mentioned are relatively trivial as contrasted with the outstanding overall merit of this text. If certainly could not be overlooked if one is seeking a text for teacher preparation. However, it should also be considered as a very valuable reference for the teacher's library—whether beginning or experienced teacher. Not only is there here collected in one place a great deal of material regarding current developments but the hints for presentation, to say nothing of the bibliographical material are invaluable. One can only say that this might be expected from writers of the caliber of Professors Butler and Wren.

CECIL B. READ
University of Wichita

ONE HUNDRED AND ONE SCIENCE EXPERIMENTS, by Illa Podendorf. Cloth. 27.5×20 cm. 157 pages. Childrens Press, Chicago, Illinois, 1960.

Within the last two or three years, a great deal of attention has been focussed on the teaching of science in the public schools. Much of the attention has been

given to the growing field of elementary-school science. Thousands of words have been written and spoken about the teaching of science in the elementary grades. But, out of all this discussion, perhaps the most frequently heard criticism is that elementary science is too much reading, and not enough "doing." Experts in the field are constantly urging that elementary science programs include more student activities and experiments.

Miss Podendorf's book should be an "answer to a prayer" for those elementary teachers and supervisors who are anxious to increase the amount of student activity in elementary science. The book, as the title indicates, is a collection of 101 simple experiments for elementary, and in some cases junior-high, students to perform. For the most part, they require only simple equipment that is available to, or readily obtainable by, an elementary teacher.

While most of the experiments are not new or unique, they are written in a simple and appealing style. In addition, each activity begins with a question, which in the opinion of the reviewer, is a "must" for a science experiment. The experiments are arranged according to broad areas. The areas included are: Air, Magnets, Electricity, Water, Heat, Sound, Light, Simple Machines, Chemistry, Plants, and "More Experiments." In addition to the activities, the materials needed for the experiments are listed, together with suggested sources where they might be obtained.

The format of the book is unusually attractive for a book of this type. It is a large book with large type and extremely colorful and attractive drawings and diagrams. It should appeal to students and teachers as well.

In the opinion of the reviewer, this book would be a welcome addition to the classroom library or professional library of any elementary school.

JACQUELINE MALLINSON
Western Michigan University

EFFECTIVE READING IN SCIENCE. A Handbook for Secondary Teachers, by David L. Shepherd, *Director of The Reading Center, Charlotte Public Schools.* Cloth. 14×20.5 cm. 128 pages. Row, Peterson and Company, Evanston, Illinois, 1960.

This book is one of the most unusual to be received in the editorial offices of this *Journal* in several months. As the title indicates, it is a handbook to assist secondary teachers in the development of reading skills in science in their students. It is interesting to note that there has been more research done in the field of reading than any other area of education. Second in line with respect to amount of research is the field of science education. This book, then, seems to be a logical blend of these two fields.

It is redundant to state that learning in science, or any other subject matter area, depends first on a student's ability to read. In addition, teachers are well aware that reading in science presents some unique problems with respect to reading. Hence, this handbook should be of value to many science teachers, particularly in the early secondary-school grades.

The book is organized into 15 sections, or chapters. Most of these sections are concerned with the development of certain skills or abilities in students. Some representative titles of sections are as follows:

Skill in varying rate of reading according to purpose of reader and nature of the material
Skill in locating and using sources of information
The ability to use correctly the vocabulary of science
The ability to understand and use formulas and scientific symbols
The ability to read directions accurately
The ability to apply data from reading to practical problems

After most of the sections there are sample lessons to illustrate the suggested techniques for the reader, and sample activities that teachers can apply in a classroom situation.

The publishers state, "this handbook is ideal for use either with in-service edu-

cation groups or by individual teachers." In the opinion of the reviewer, this is a justified comment. However, it would appear that the book would also have value for pre-service teacher candidates.

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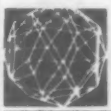

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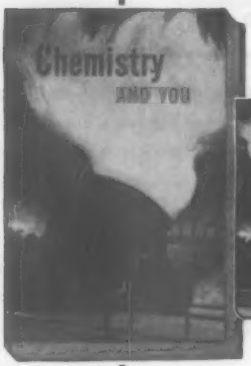

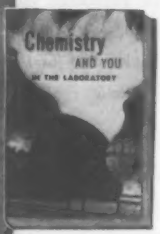

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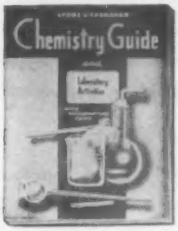

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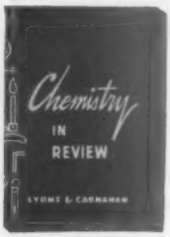

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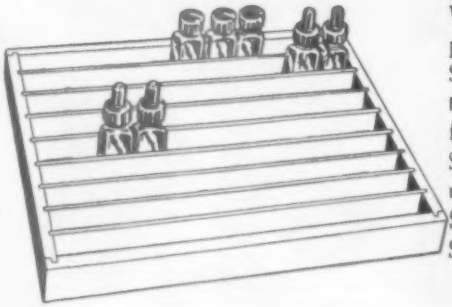

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